OPEN-PIT COPPER MINING METHODS AT NEW CORNELIA BRANCH, PHELPS DODGE CORP., PIMA COUNTY, ARIZ.

By W. R. Hardwick

* * * * * * * * * * * * * information circular 7938

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

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OPEN-PIT COPPER MINING METHODS AT NEW CORNELIA BRANCH, PHELPS DODGE CORP., PIMA COUNTY, ARIZ.[1]

by

W. R. Hardwick[2]

SUMMARY AND INTRODUCTION

This information circular describes mining methods and practices at New Cornelia Branch, Phelps Dodge Corp., Ajo, Ariz. It is one of a series being prepared by the Bureau of Mines on mining methods, practices, and costs in various mining districts of the United States.

The New Cornelia mine (fig. 1) is at Ajo, a town in southwestern Arizona (fig. 2) on Arizona State Highway 85 in the western part of Pima County. The concentrator and smelter are near the mine (fig. 3).

Copper ore is mined, crushed, ground, and concentrated, and the concentrates are smelted. Copper is cast in anode form and sent to the Phelps Dodge Corp. refinery in El Paso, Tex.

This report gives a brief history of the district and a general description of the geology of the ore deposit; and it outlines methods of exploration, sampling, and ore estimation. Development and mining, including breaking ground, loading, ore and waste transportation, and engineering and operating control, are explained. Auxiliary operations, ore extraction, production rates, safety measures, fire protection, mine drainage, and mine organization are described briefly, and processing operations are outlined. Costs are not available for publication.

ACKNOWLEDGMENT

Acknowledgment is made to executives and staff of the Phelps Dodge Corp. for permission to publish this paper. Special acknowledgment is due Alfred T. Barr, manager, and John A. Lentz, former general superintendent of New Cornelia Branch of Phelps Dodge Corp.

Manufacturers have been generous in supplying specifications for equipment.

1/ Work on manuscript completed June 1959.

2/ Mining engineer, Bureau of Mines, Region III, Tucson, Ariz.

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The New Cornelia mining operation was described by Ingham and Barr[3/] in 1932, geology of the Ajo mining district was described by Gilluly;[4/] and maps and drawings were furnished by the mining company, except where otherwise noted. Information from these sources has been used freely and, with information gathered from lengthy discussions with members of the operating and engineering staff, was valuable in preparing this paper. Other published articles are acknowledged by footnotes to the report.

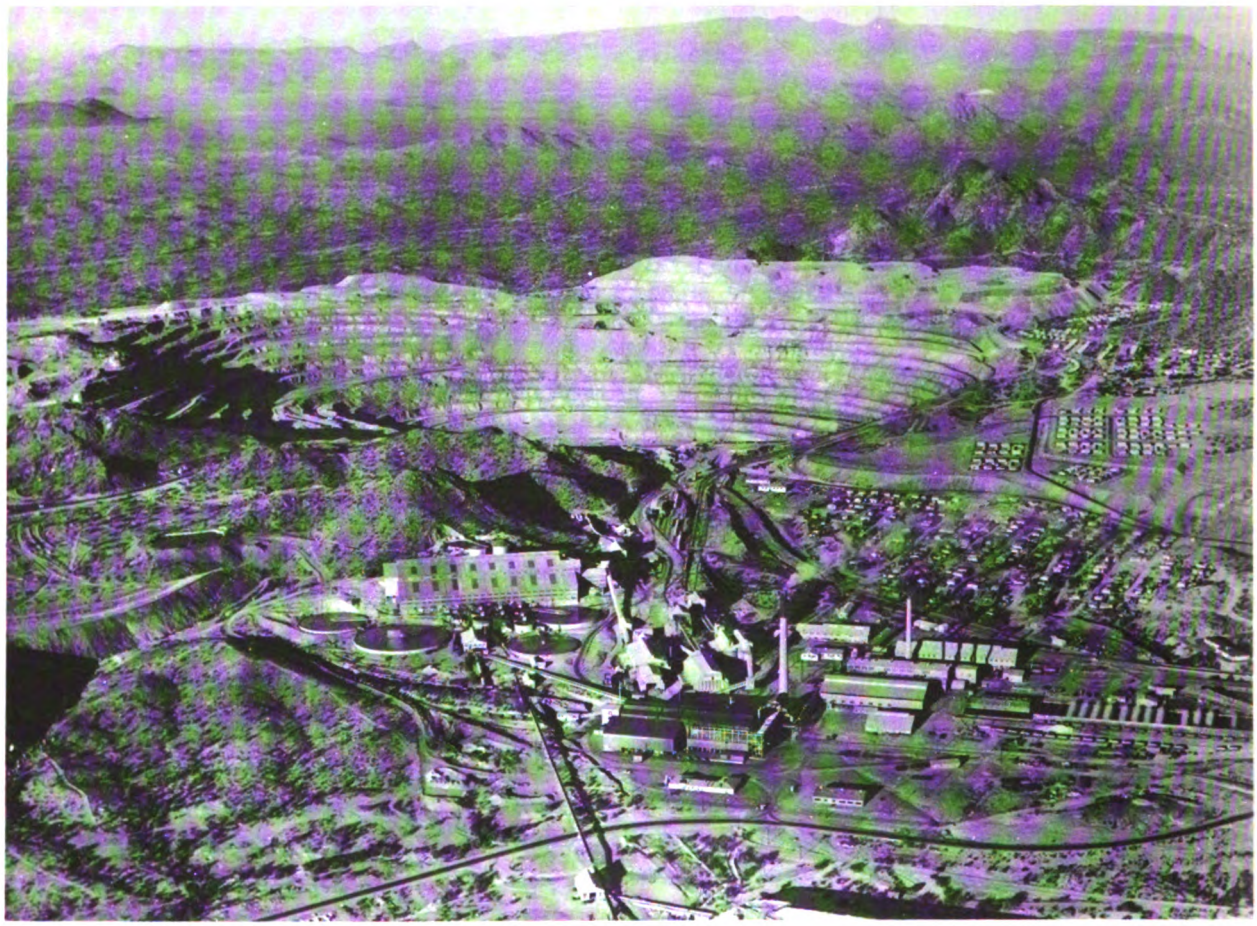

FIGURE 1. - New Cornelia Mine.

HISTORY OF THE DISTRICT

The New Cornelia copper deposit is in secs. 26 and 27, R. 6 W., T. 12 S., Gila and Salt River base and meridian, along Arizona State Highway 85

3/ Ingham, George R., and Barr, Alfred T., Mining Methods and Costs at the New Cornelia Branch, Phelps Dodge Corp., Ajo, Ariz.: Bureau of Mines Inf. Circ. 6666, 1932, 18 pp.

4/ Gilluly, James, The Ajo Mining District, Arizona: Geol. Survey Prof. Paper 209, 1946, 112 pp.

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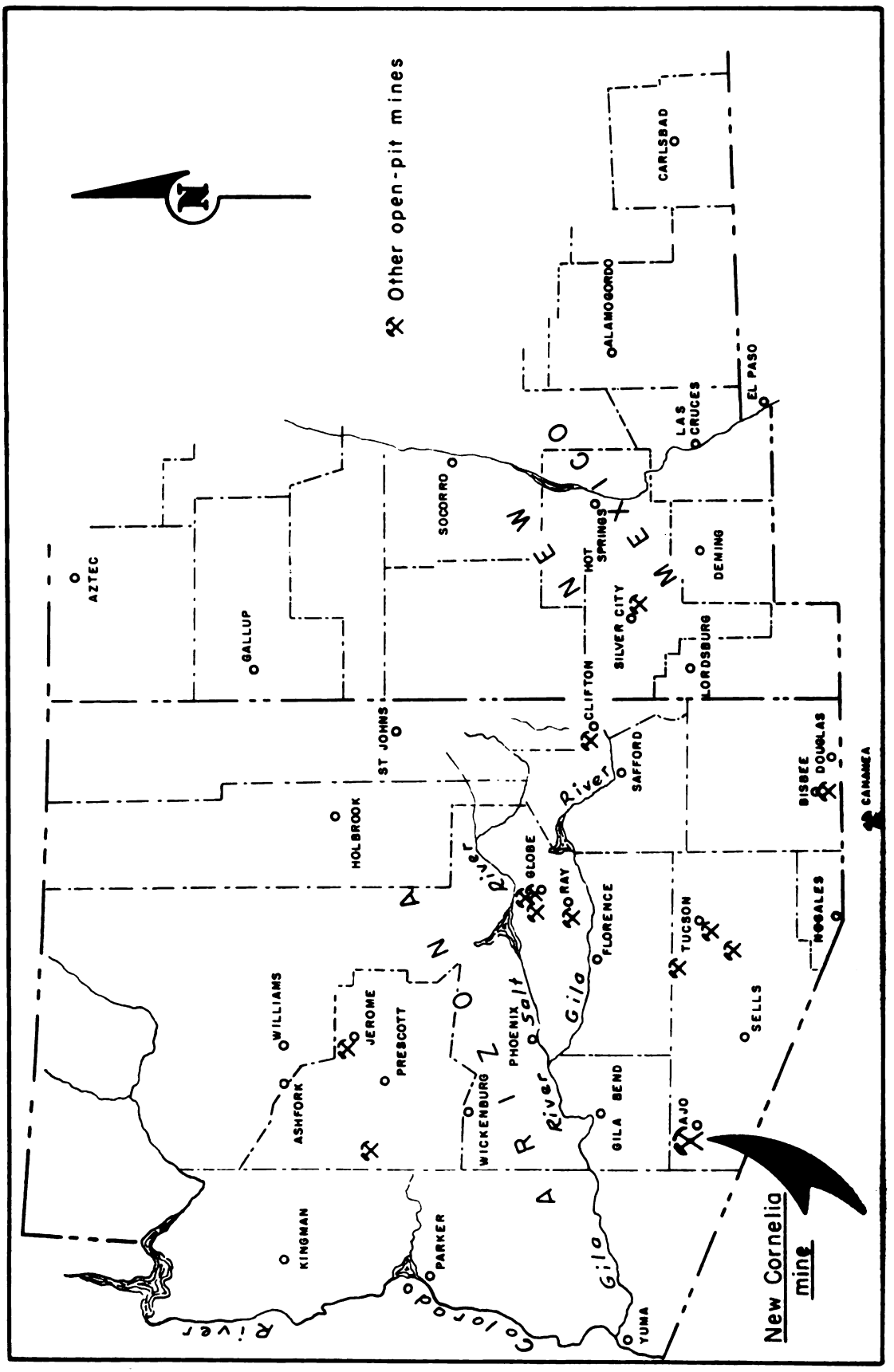

FIGURE 2. - Location of Open-Pit Copper Mines in Arizona and New Mexico.

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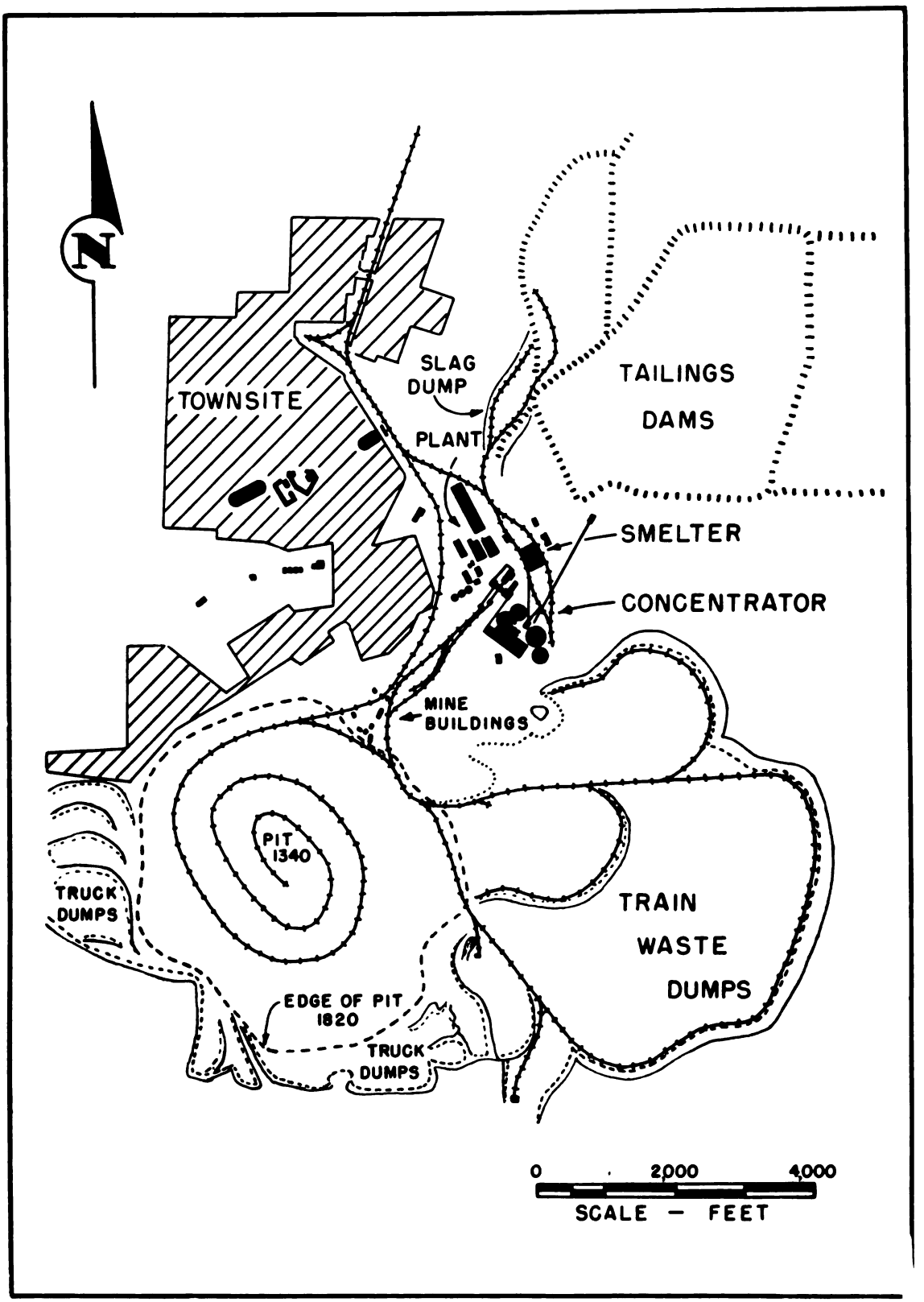

FIGURE 3. - Sketch Map, Open-Pit Mine and Plant, Ajo, Ariz.

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and 42 miles south of Gila Bend, a town on U. S. Highway 80. The mine and town are in the western end of Pima County. The area contains several small mountain ranges, but much of it is covered by alluvium; local relief is mild. Altitude ranges from 1,150 to 3,200 feet, and the mine is at about 1,800 feet. The climate is arid; rainfall ranges from 7 to 10 inches per year, and there are no permanent streams. The temperature ranges from 20° to 115° F., with many days over 100° F. in the summer.

The copper deposit at Ajo was one of the first to be discovered in the Southwest. The first mining of copper by Americans in Arizona[5/] reportedly was done near Ajo in 1854, although the occurrence of copper had been established as early as 1750. Before 1900 mining was confined to small bodies of high-grade ore. This ore was hauled in wagons to Yuma or San Diego and then was transported via sailing ship to Swansea, Wales. From 1900 to 1910 greater interest was shown in the low-grade ores of the district as a result of the success of the Utah Copper Co. at Bingham. Numerous claims were located,[6/] and some of them were examined by prominent mining companies.

By 1917 the important claims had been acquired by New Cornelia Copper Co., which had been consolidated with the Calumet & Arizona Mining Co. of Calumet, Mich. This company was merged with Phelps Dodge Corp. in 1931, and thereafter the Ajo mine was known as the New Cornelia Branch, Phelps Dodge Corp.

Two factors that retarded early development of the Ajo district were inadequate transportation and scarcity of water. The transportation problem was solved by the construction of a standard-gage railroad from Ajo to Gila Bend, a station on the east-west main line of the Southern Pacific Co. This spur line is known as the Tucson, Cornelia, and Gila Bend Railroad.

Prospecting for water was begun in 1913.[7/] When the mine was in the exploration and development stages, the only water available was from shallow wells, and the supply was limited. Later, prospect wells were drilled in the Ajo Valley about 7 miles north of the mine, and an adequate supply was discovered at a depth of 645 feet. The first well tested produced a strong flow of water. A shaft was sunk, and pumps and pipeline were installed. With additional development, this well has continued to supply the mine, concentrating plant, and townsite.

In May 1913 test pits and sample drill holes indicated an ore body that cropped out over an area of 100 acres. It was estimated to contain 12,000,000 tons of carbonate ore averaging 1.54 percent copper. A workable leaching method[8/] was developed, and a plant with a daily capacity of 5,000 tons was completed in 1917. This plant was operated until July 1930, when all available carbonate ore had been treated.

5/ Tuck, Frank J., History of Mining in Arizona: Arizona Dept. Mineral Resources, Phoenix, Ariz., 1955, 40 pp.
6/ Work cited in footnote 3 (p. 2).
7/ Barr, Alfred T., and Sandberg, Edward D., The Part Water Plays in Mining: AIME, Arizona Sec., October 1941, 16 pp.
8/ Work cited in footnote 3 (p. 2).

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Drilling proved that sulfide ore with about the same copper content existed below the carbonate ore. By 1923 much of the carbonate ore was removed, and the sulfide ore was developed to sustain a daily production of 5,000 tons. A flotation concentrator of this capacity was built, and sulfide-ore production began in January 1925. The capacity of the concentrator was increased from time to time by additions and improvements to equipment and operating efficiency, until in 1956 the concentrator was processing 31,503 tons of ore per day.

Before 1950 all concentrates from the New Cornelia Branch were shipped to Douglas, Ariz., for smelting. In that year a smelter was constructed at Ajo and placed in service.

The original diamond drilling of the New Cornelia ore body proved 40,000,000 tons of sulfide ore, but the production before 1917 was probably less than 1,700,000 pounds of copper.9/ As of January 1957 the New Cornelia mine has produced 3,266,775,883 pounds of copper from 17,027,398 tons of carbonate ore and 183,118,558 tons of sulfide ore. To produce this ore and to prepare for future mining, 183,066,430 tons of waste was mined. During 1956 the mine was producing ore at the rate of 31,503 tons and waste at the rate of 45,184 tons per operating day.

No other ore body discovered in the district has been developed into a producing mine.

DESCRIPTION OF THE DEPOSIT

The New Cornelia ore body differs from all other great disseminated-copper deposits of the Southwest in three important respects: There was no leached overburden, the sulfide minerals in the ore were of primary origin, and the oxidized portion of the ore body was amenable to a recovery process and of an economic grade.

The original outcrop covered approximately 100 acres. It was in the southern end of a body of quartz-monzonite porphyry that crops out over an area of about 6 square miles. The mineralized outcrop was in the form of a rough ellipse, approximately 3,600 by 2,500 feet. The average thickness of the ore was 425 feet and the maximum about 1,000. The altitude of the surface around the edge of the open pit ranges from 1,790 to 2,075 feet and averages about 1,800 feet. Bench levels in the mine and ore-reserve calculations are referred to sea level.

The geology has been described by Gilluly.10/ The oldest rocks of the district (Cardigan gneiss, hornblendite, and hornfels) have been invaded by the Chico Shunie quartz monzonite and, after a period of erosion, covered by the Concentrator volcanics. This complex has been intruded by the Cornelia quartz-monzonite porphyry, which was shattered and cracked, then permeated by magmatic solutions that deposited the ore minerals and solidified the rock.

9/ Gilluly, James, Ajo District, Copper Resources of the World: 16th Internat. Geol. Cong., vol. 1, Washington, 1935, p. 230.

10/ Work cited in footnote 4 (p. 2).

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After some further volcanic activity the ore body was subject to a period of erosion that removed the covering rocks and the upper part of the ore body. During this erosional period ore minerals were oxidized, leached, and carried downward by supergene water, where they were deposited, probably at permanent water level, to form a thin blanket of chalcocite ore. A thick series of fanglomerate interbedded with volcanic rocks covered the surface, and then the whole block was tilted until the original surface dipped about 60° to the south.

After additional volcanic activity the present erosion cycle truncated the ore body for the second time. This exposed the primary ore and the outcrop of the zone of secondary enrichment that remained from the first erosion period. This time there was no migration of the copper: The sulfide minerals were oxidized in place and formed carbonates, silicates, and, in some instances oxides of copper. The contact between the oxidized and unoxidized part of the ore body generally followed the topography at a relatively uniform elevation. Oxidized ore ranged from 20 to 190 feet in depth and averaged about 55 feet. The copper content and distribution were similar for both oxidized and sulfide ore.

Some rocks along the older erosional surface exhibit the soft, chalky appearance common to most of the porphyry-copper ore bodies. However, monzonite in most of the ore body contains much quartz and orthoclase and is an extremely hard, fresh-appearing rock. The ore body is almost entirely in quartz monzonite, but some of the older volcanic rocks are mineralized (fig. 4).

The primary ore minerals are chalcopyrite and bornite. Pyrite is more abundant on the north and east fringes of the ore body, occurring in veinlets. A narrow band of chalcocite ore occurs along the southern limits of the sulfide ore and dips steeply to the south along the old erosional horizon. The copper content is not uniform in the ore body; there are areas of waste that range from 0.10 to 0.40 percent copper and average about 0.25 percent (figs. 5, 6, and 7).

Minerals of the oxidized ore were malachite, azurite, cuprite, tenorite, and chrysocolla. Typical oxidized ore mined during 1928 contained 1.13 percent total copper of which 1.00 percent was acid-soluble copper and 0.13 percent was sulfide.11/

Shattuckite, a hydrated copper silicate, occurs as veins in the rhyolitic Concentrator volcanics along the southwest side of the ore body. One vein persisted for a length of 50 to 100 feet over a vertical range of about 100 feet. In places it was as much as 1 foot thick but normally was about 3 inches. The rare copper mineral shattuckite has a rich blue color when polished and is much in demand locally by mineral collectors for semiprecious jewelry. Some bisbeeite, also a silicate, is associated with the shattuckite and is probably on alteration product.

11/ Bell, George A., Leaching Practice and Costs at the New Cornelia Mines of the Calumet and Arizona Mining Co., Ajo, Ariz.: Bureau of Mines Inf. Circ. 6303, 1930, 30 pp.

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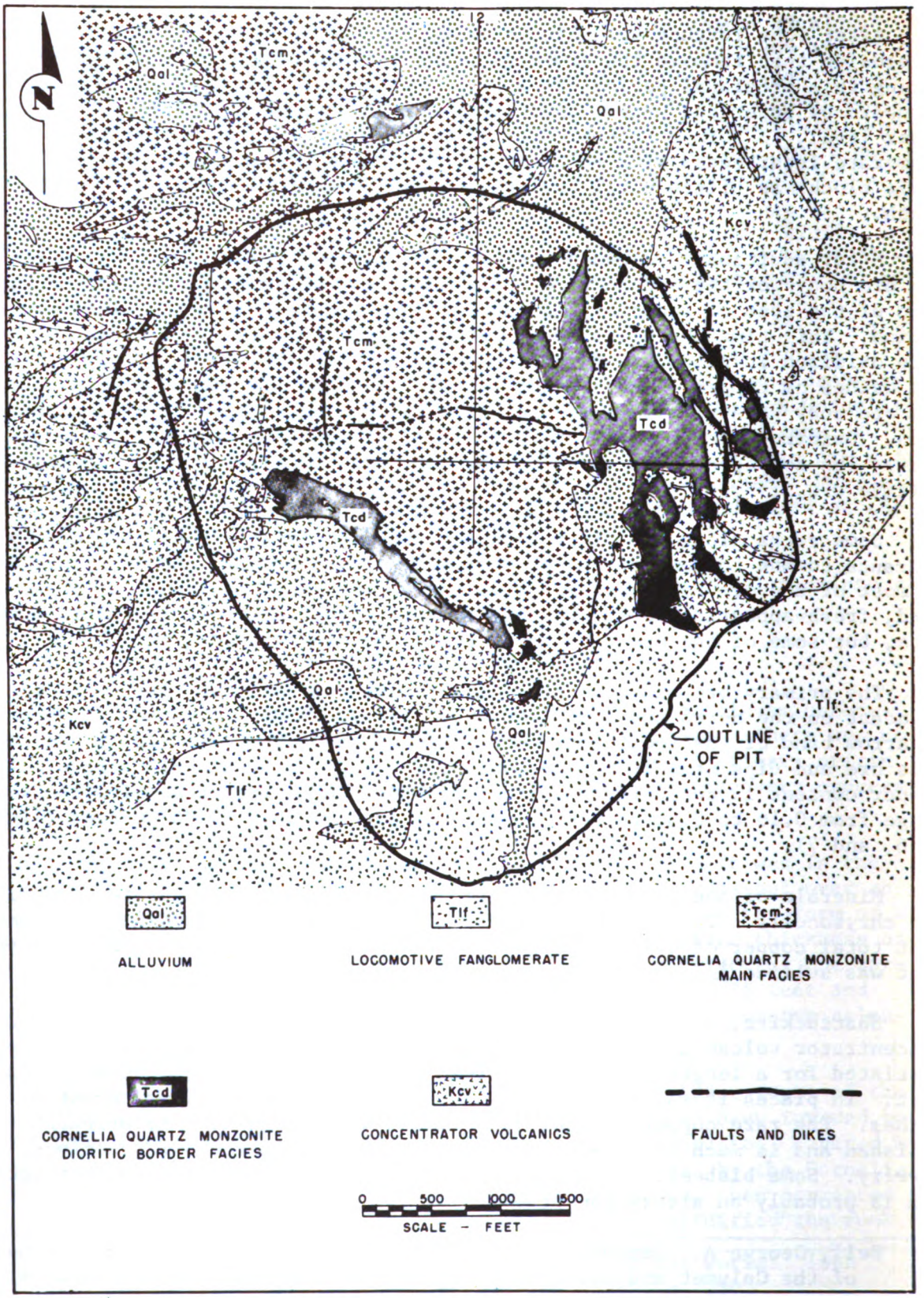

FIGURE 4. - Geologic Map of the New Cornelia Mine.
(Geology from Geological Survey Prof. Paper 209, plate 21.)

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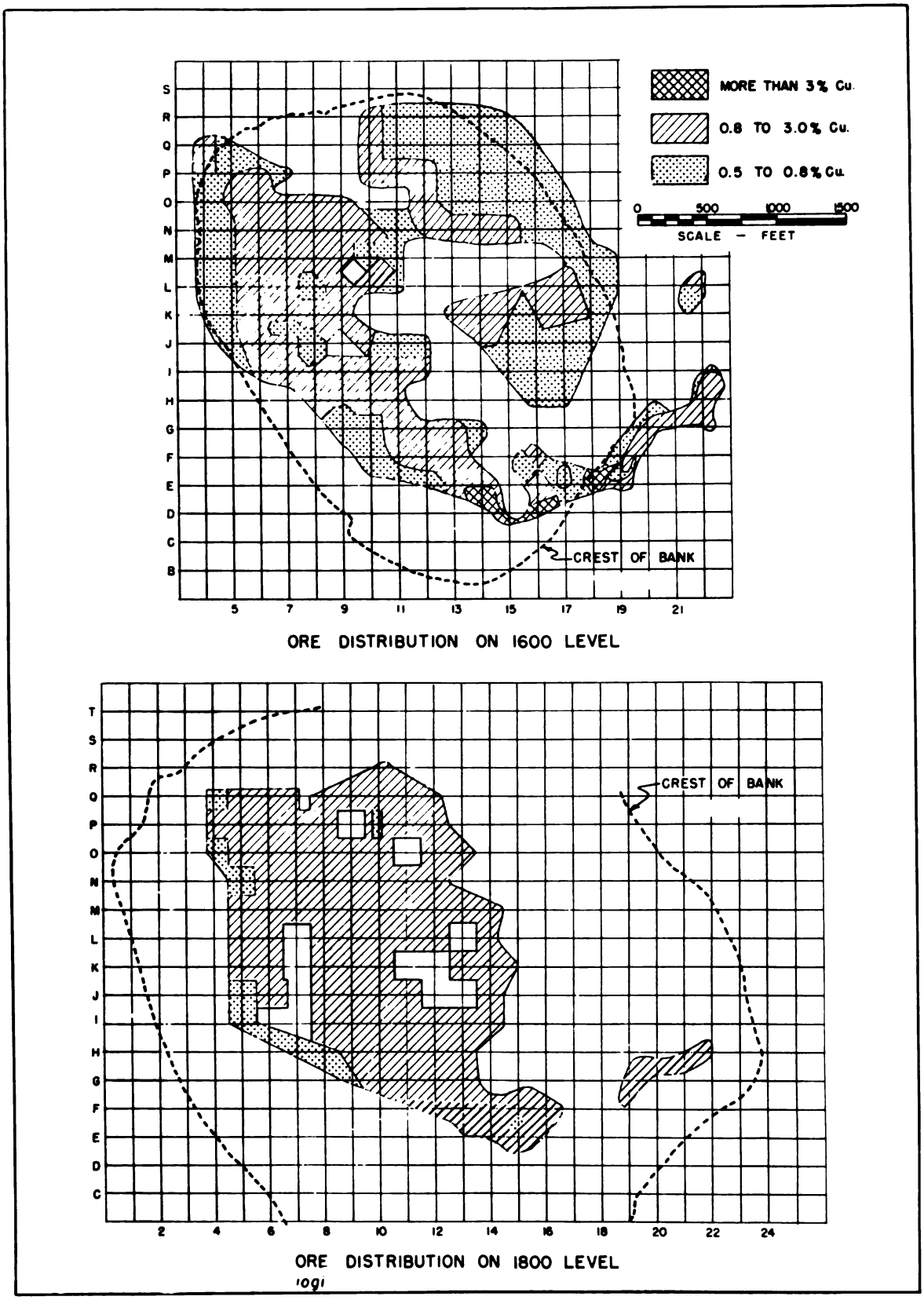

FIGURE 5. - Plan of 1,800 and 1,600 Levels, New Cornelia Mine.
(Ore distribution from Geological Survey Prof. Paper 209.)

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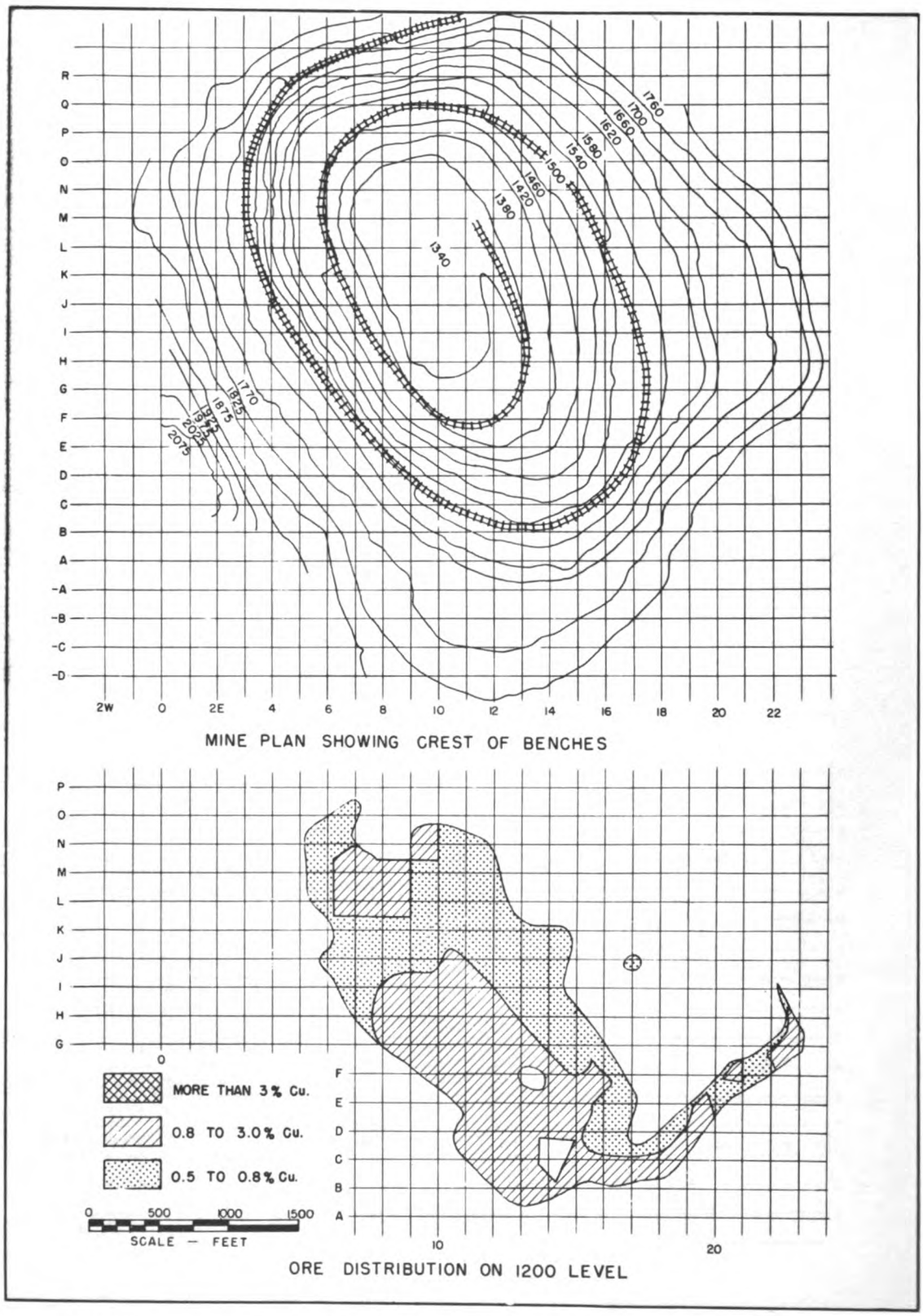

FIGURE 6. - Plan of 1,200 Level and Surface, New Cornelia Mine.
(Ore distribution from Geological Survey Prof. Paper 209.)

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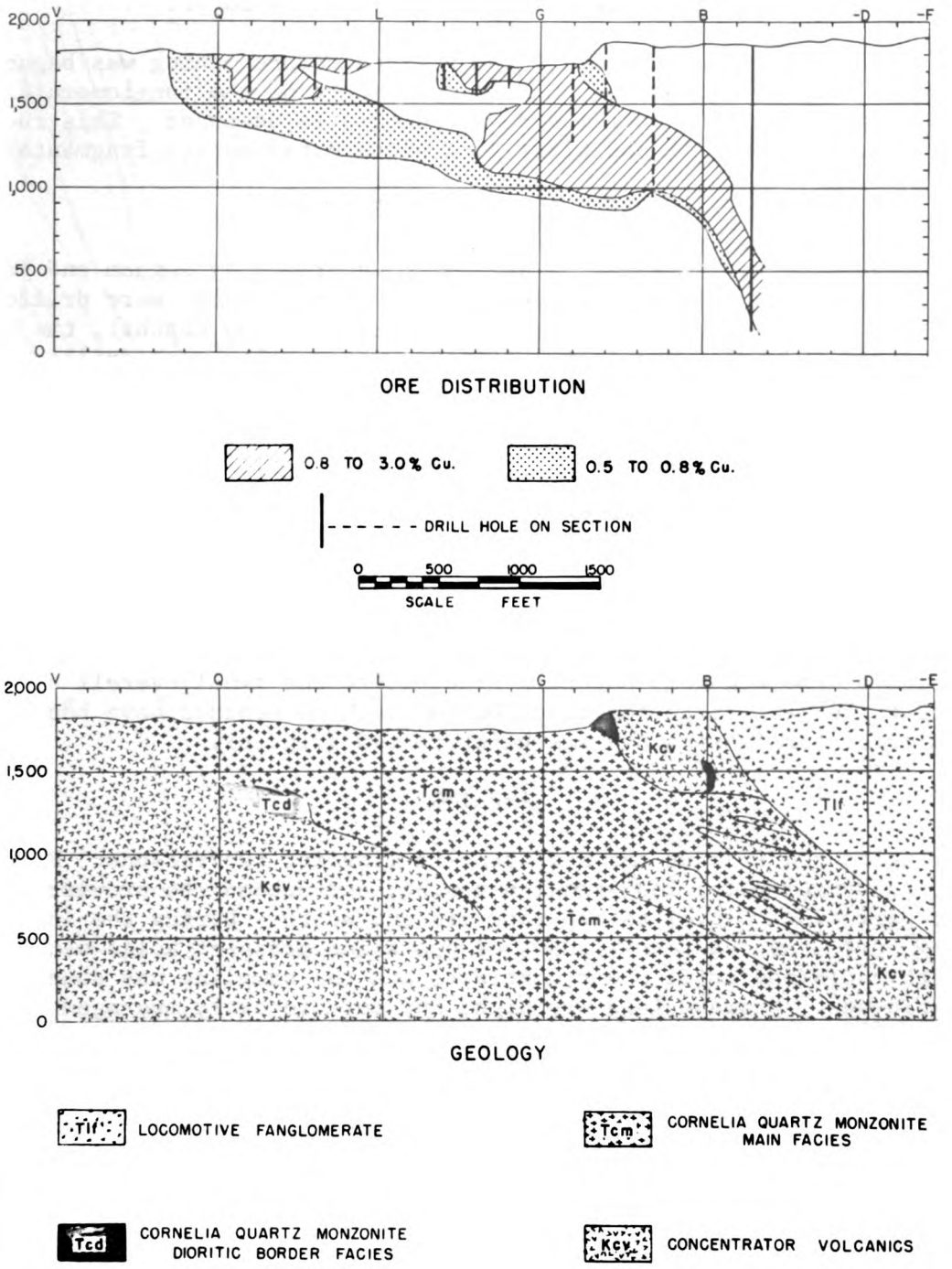

FIGURE 7. - Sections Through Coordinate 12.
(Geology from Geological Survey Prof. Paper 209.)

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The physical characteristics of the New Cornelia ore and enclosing rocks present several features different from the average porphyry-copper deposit. The ore minerals are fresh, clean chalcopyrite and bornite, with only a trace amount of acid-soluble copper, whereas the ore mineral found in many of the porphyry-copper deposits is chalcocite, and the soluble copper is significant.

There was no barren overburden to be removed before mining was begun, as is usual in developing an open-pit mine. Some parts of the fanglomerate on the south side of the mine must be removed as the mine is deepened. This rock is extremely difficult to drill and blast to achieve satsifactory fragmentation.

PROSPECTING AND EXPLORATION

The prospecting and exploration have been described by Ingham and Barr.12/ Before 1926, 178 diamond-drill holes and 14 churn-drill holes were drilled to delineate the ore body (most of them to relatively shallow depths), the average depth of all 192 holes was only 365 feet. These holes were drilled on north-south and east-west coordinates at 200-foot intervals. Later more information was desired, and 58 additional holes were drilled at 400-foot intervals to an average depth of 976 feet. Finally, as the mine approached the depth of the shorter holes, these were deepened to provide adequate information for long-range planning. In the initial prospecting, test pits were dug to check the results of the drilling in carbonate ore, and drifts and raises were driven to check the sulfide ore.

The ore reserves were calculated on an estimated ultimate waste to ore ratio of 0.90:1.00 and a planned final overall pit slope of 1:1, except on the west side of the Arkansas Mountain area, where the final overall slope was planned to be 1-1/3:1 on the upper benches. Some benches have been prepared to a trial final slope and are being tested (fig. 8).

SAMPLING

Sampling is required at the New Cornelia mine for two reasons: First, to provide information for long-range planning; and second, to provide information for operating control to separate ore and waste. During the initial prospecting period and the early years of operation prospect holes were drilled with a diamond drill under contract, and the sampling was done by company employees. Diamond loss was high, and core recovery averaged only 49.8 percent.13/

Electrically powered churn drills and mechanical bit-sharpening machines were adopted for blasthole work at Ajo in 1936.14/ With this equipment, holes could be drilled more economically. Tests were made, and, in some instances, churn-drill holes were drilled at points where parts of former diamond-drill holes had not been completely dug out. A comparison of the sample results from the churn drill with those from the former diamond drill for the same

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12/ Work cited in footnote 3 (p. 2).
13/ Work cited in footnote 3 (p. 2).
14/ Angst, Harry A., and Cochrane, Ruel A., Blasting practice at the New Cornelia Open Pit Copper Mine: Trans. AIME, vol. 153, 1943, pp. 233-247.

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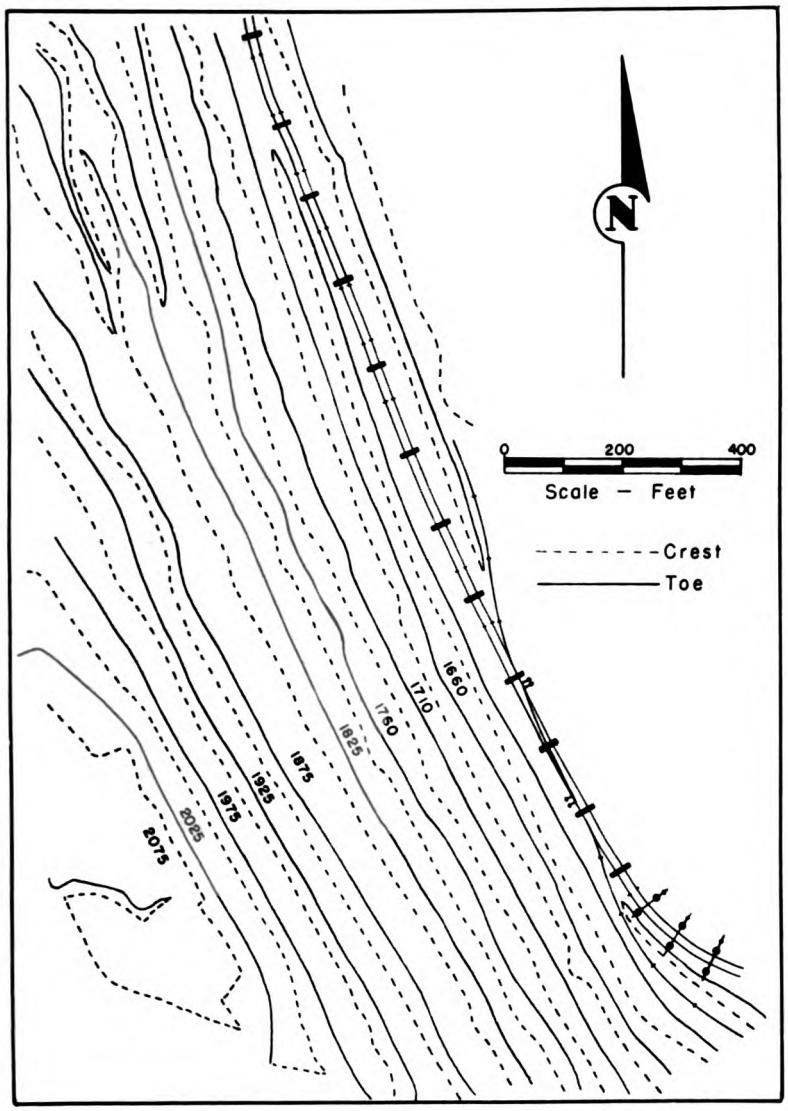

FIGURE 8. - Plan of Banks Trimmed to Trial Final Slope.

vertical interval indicated that the new method of drilling produced sample results comparing favorably with those from the diamond drill.

Drill holes are started large enough to accommodate a 12-inch-diameter casing; when caving ground is encountered, the hole is cased, and the size of the bit is reduced. The sludge is bailed from the hole with a dart bailer and sand pump and emptied into a special splitter developed at Ajo. This splitter (fig. 9) takes a 1/16 cut from the center of the sludge stream. The sample is collected in a tub and then split wet through 1-inch slots on an 18-inch Jones-type splitter to a weight of approximately 10 pounds. The sample is listed on a form (fig. 10) and sent to the sample mill in 2-gallon cans. After drying, the sample is reduced to laboratory size and assayed by the iodate method.

Drill holes are spotted at the corners of 200-foot squares, and samples are taken for 5-foot vertical intervals. Records of assays and geological information are entered on a permanent drill-hole log. Small fragments of rock from each sample are washed and glued to a board for a visual record. Complete chemical analyses are made on composite samples representing 50-foot intervals. The sample is prepared for assay in the sample mill in the same manner as a regular mine sample (fig. 11) except that all rejects from the 1-pound split are stored indefinitely for possible future use.

ESTIMATION OF TONNAGE AND GRADE

Horizontal sections or level plans are made, and all drill holes that intersect these sections are plotted on them. All of the assays for the 5-foot sample intervals that are included in the level interval are averaged,

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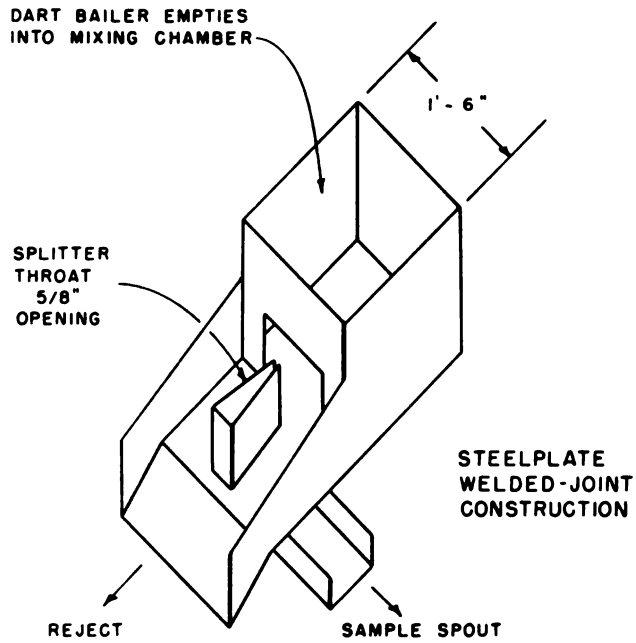

FIGURE 9. - Churn-Drill Sample Cutter.

and this value is assigned to the area of influence for the drill hole. The area of influence for a drill hole is determined by a polygon bounded by sides perpendicular to and at the midpoint of radial lines to the surrounding holes.

The area of the polygon is scaled with the aid of a planimeter and multiplied by the level interval to give cubic feet. A factor of 12-1/2 cubic feet per ton is used. A work sheet is set up using the following column headings: Planimeter reading, cubic feet, tons, percent copper, and tons x percent. The total of the "tons x percent" column divided by the total of the "tons" column gives the grade for the area or level under consideration.

Initial plans were made on a scale of 1 inch per 100 feet, and vertical sections were made on a scale of 1 inch per 40 feet. Because those drawings were unwieldy, a second set of level maps and sections was made on a scale of 1 inch per 200 feet. For planning purposes estimates are made for 1-, 5-, and 10-year periods. These estimates, complete in detail, are necessary to assure orderly development.

DEVELOPMENT AND MINING

General

The New Cornelia open-pit mine has the form of a rough oval, 5,000 feet long and 4,600 feet wide. The major axis runs about 30° southeast. All of the benches in the upper part of the south and west sides of the mine are in waste. A main-line, double-track railroad enters the mine at the northeast corner and spirals to the bottom on a 3-percent grade compensated for curves. A second approach track is provided at the east side of the mine on a 2-percent grade for waste haulage from the upper levels.

Blastholes ranging from 3 to 12 inches in diameter are drilled with percussion, rotary, or churn drills along banks that range from 33 to 50 feet high and average 40 feet. Breaking boulders and secondary drilling and blasting are important functions. A 3:1 overall slope in working areas is necessary to maintain a minimum operating width on active levels, but benches will be pushed back to the final 1:1 slope as they are completed.

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Form 154 -- 5M

PHELPS DODGE CORPORATION
New Cornelia Branch
ENGINEERING DEPARTMENT

SAMPLE COLLECTION REPORT

Signed..... **Date**.....

Sample No.	Level No.	Sample No.	Level No.

FIGURE 10. - Sample Collection Report.

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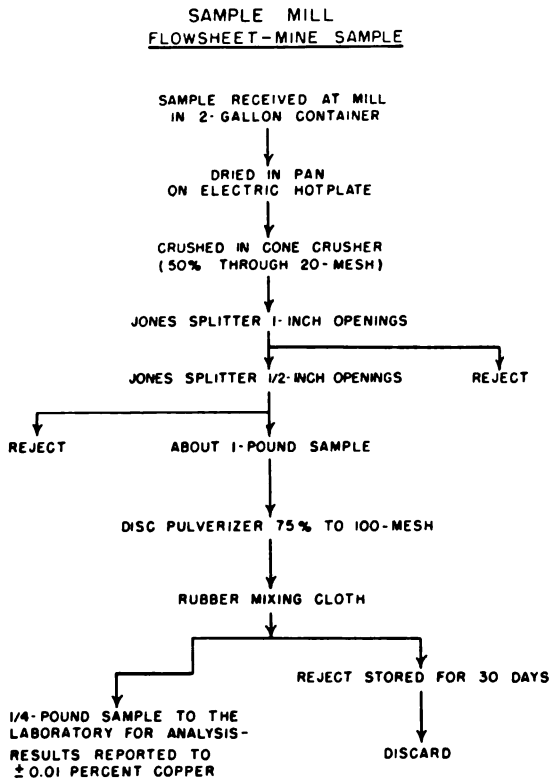
SAMPLE MILL
FLOWSHEET-MINE SAMPLE
SAMPLE RECEIVED AT MILL IN 2-GALLON CONTAINER
DRIED IN PAN ON ELECTRIC HOTPLATE
CRUSHED IN CONE CRUSHER (50% THROUGH 20-MESH)
JONES SPLITTER 1-INCH OPENINGS
JONES SPLITTER 1/2-INCH OPENINGS
REJECT
REJECT
ABOUT 1-POUND SAMPLE
DISC PULVERIZER 75% TO 100-MESH
RUBBER MIXING CLOTH
REJECT STORED FOR 30 DAYS
1/4-POUND SAMPLE TO THE LABORATORY FOR ANALYSIS-RESULTS REPORTED TO ±0.01 PERCENT COPPER
DISCARD

FIGURE 11. - Sample-Plant Flowsheet, Mine Samples.

Full-revolving electric shovels equipped with dippers that range from 6 to 9 cubic yards load ore and waste into standard-gage 30 or 32-cubic-yard side-dump cars. Electric with diesel auxiliary, or diesel electric locomotives haul seven-car trains of ore or waste from the pit. Some stripping waste is hauled by truck. Waste dump and concentrating plant are located near the mine. Pumps in churn-drill holes drain ground water to a level below the lowest operating level.

The cycle of operations consists of drilling, blasting, loading, hauling, and disposal of ore and waste. These operations, with such auxiliary phases as track and road preparation and maintenance, are discussed in the following sections.

Breaking Ground

The ground at the New Cornelia mine can be divided into three types for drilling and blasting purposes:

1. Fanglomerate, a massive bedded rock, generally with no fracturing evident. The rock is drilled with difficulty and tends to break into massive blocks with relatively little shattering.

2. Hard, fresh-appearing, quartz monzonite and diorite, somewhat fractured.

3. Highly fractured and intensely altered monzonite and Concentrator volcanics.

These different types of ground require a variety of equipment. Some of the rock types are particularly difficult to break, and the selection and use of explosives are of primary importance. The breaking-ground department is organized under the supervision of a drilling and blasting foreman who reports directly to the general foreman of the open-pit division. Office space and an office clerk are provided for filing records and consolidating reports. Delivery of bits and supplies to drills is supervised by the department. Drill repair is supervised by the general repair foreman.

A map of the mine is posted in the drilling and blasting office, and pins numbered to correspond with the drill they represent show the location of all drills. From a review of the drilling reports for the preceding day, a drill-lineup form is completed. This form lists the drills as operating or unable to operate and indicates which drills are to be operated and which are

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to be used as extras. From it, the primary drill foreman selects drills and assigns operating crews for the oncoming shift.

The general cycle for breaking ground includes the following steps:

1. Secondary drilling (a) along the cleaned-up face to break large boulders evident in the face of the bank or that the shovel has set back from the previous cut; (b) along the toe of the bank for grade when necessary.

2. Primary drilling along the crest and, if necessary, in toe holes along the bank.

3. Loading and blasting primary holes.

4. Breaking boulders with drop ball, block hole, or adobe blasting along toe of blasted bank before splatter cut.

5. Secondary drilling after splatter cut with travel drill. Where numerous boulders have been set out by the shovel, the drop ball may make a second pass before the cleanup cut.

When a hard toe is encountered in the digging pit, holes are drilled with a jackhammer or, if suitable, one of the other types of portable air-drill machines.

Primary Drilling

Before 1936 benches were 25 feet high, and primary drilling was accomplished with wagon drills or with a heavy jackhammer-type drill suspended from a tripod.15/ About that time the old railroad-type steam shovel was replaced with full-revolving electric shovels, and experiments proved that costs could be reduced by increasing the height of the benches. Two 25-foot benches were combined, making the banks approximately 50 feet high. Because this height was beyond the economic limit of air drills then in use, electrically driven churn drills were tested and found to be satisfactory. Later the height of the bench was reduced to 33 feet in fanglomerate and 40 feet in other type of rock (fig. 12).

A self-propelled, spudder-type churn drill was adopted. This drill used a 2,700-pound string of tools to drill a 9-inch-diameter hole and was the "workhorse" of the primary drilling crew for several years. Later it was replaced with a heavier machine swinging a 5,000-pound string of tools capable of drilling 12-inch-diameter holes (fig. 13).

The first few feet of drilling in a blasthole is through material broken from the previous blast. A short length of casing must be used to prevent this material from sloughing in and filling the hole. This casing must be left in place until the hole has been loaded and blasted. As the blasting resulted in much damage to the costly casing, a method was developed at Ajo

15/ Gardner, E. D., Drilling and Blasting in Open-Cut Copper Mines: Bureau of Mines Bull. 273, 1927, p. 24.

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whereby casing can be removed from the hole before blasting. Portland cement is added to the churn-drill sludge as the hole is started, and the hole is "spudded" until the casing can no longer be driven. Then the sludge-cement mixture is bailed out and placed in the subsided area around the outside of the casing, effectively bonding the loose, broken material (fig. 14) 16/ The hole is completed, and the steel casing is removed before the mortar has hardened. This method of collaring holes has resulted in a substantial saving in the amount of steel casing that must be straightened, and only about 20 feet of casing is discarded each day.

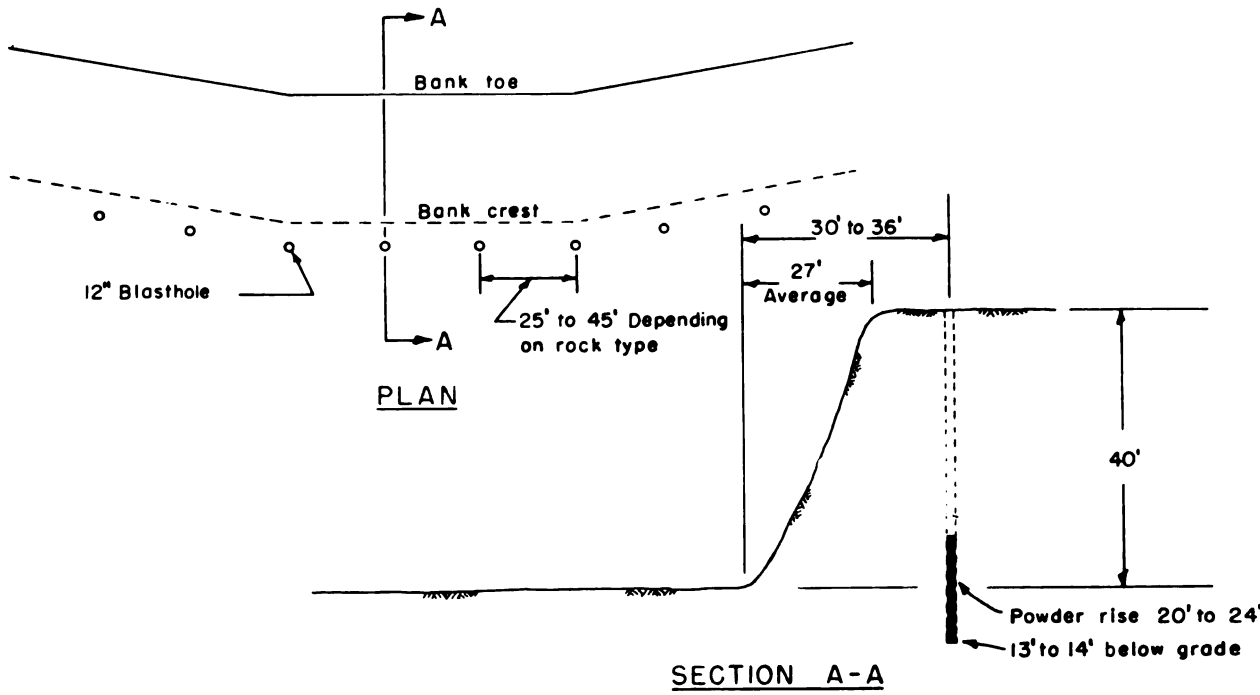

FIGURE 12. - Arrangement of Churn-Drill Holes in Bank, New Cornelia Mine.

A daily churn-drill report is made by the operating crew for each shift (fig. 15). Information from this form is consolidated by the drilling and blasting clerk into a report of churn-drilling operations for the shift (fig. 16) and later into a daily report of churn-drilling operations that includes all drilling for the 24-hour period (fig. 17). This is the final report of the drilling and blasting operations that is sent to the mine superintendent.

From the daily reports by the drill operators, a list of materials and supplies that are required at the drills is made, and these supplies are delivered to the drill by a supply truck. The truck operator completes a churn-drill supply report (fig. 18), which shows the supplies delivered to the drills visited. The churn-drill foreman submits a daily drill-availability

16/ Cratty, Donald R., Recent Changes in Drilling Practice at Ajo: AIME Open Pit Div., Arizona Sec., Inspiration, Ariz., May 7, 1951, 5 pp.

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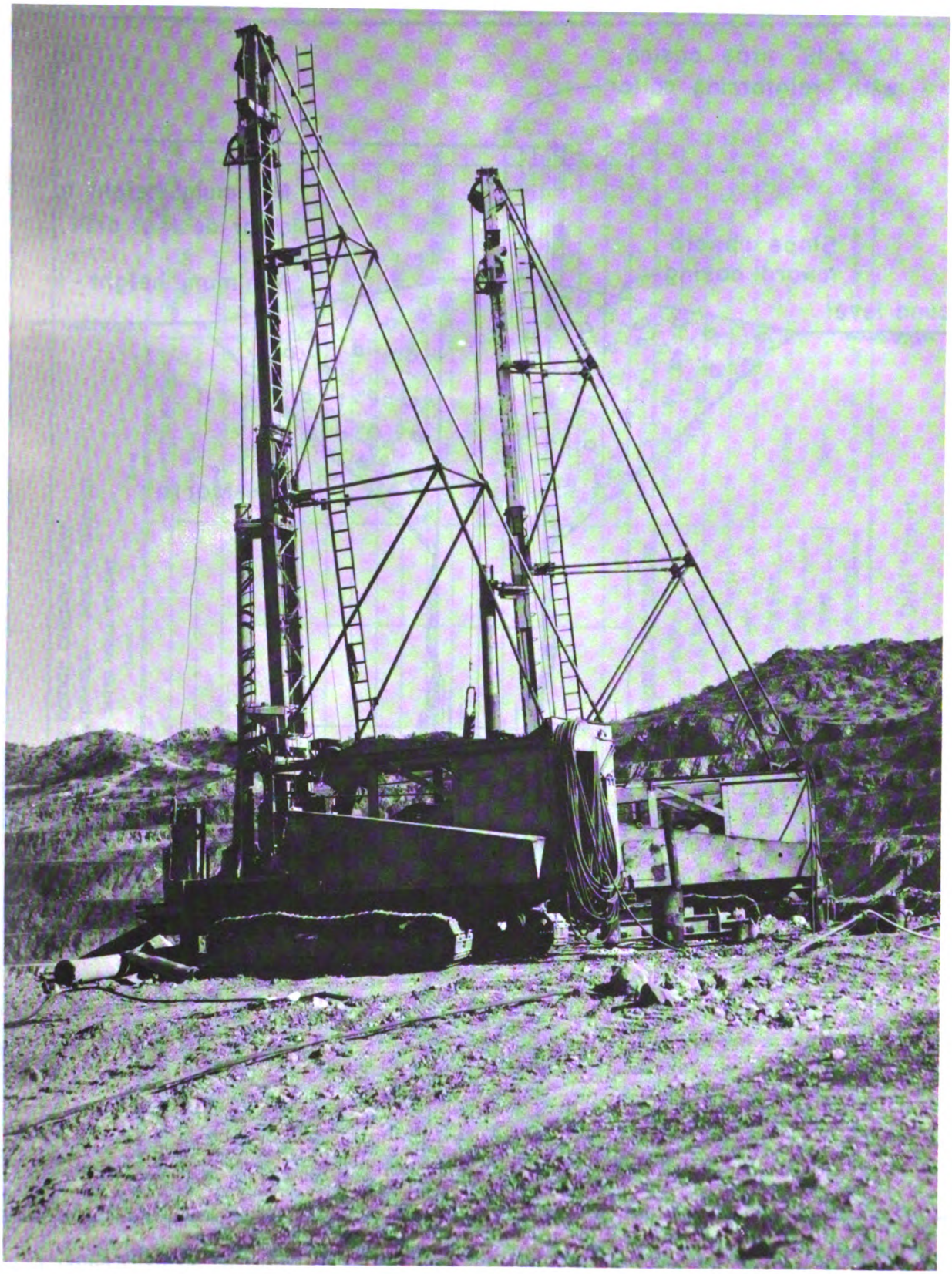

FIGURE 13. - Heavy-Type Churn Drill.

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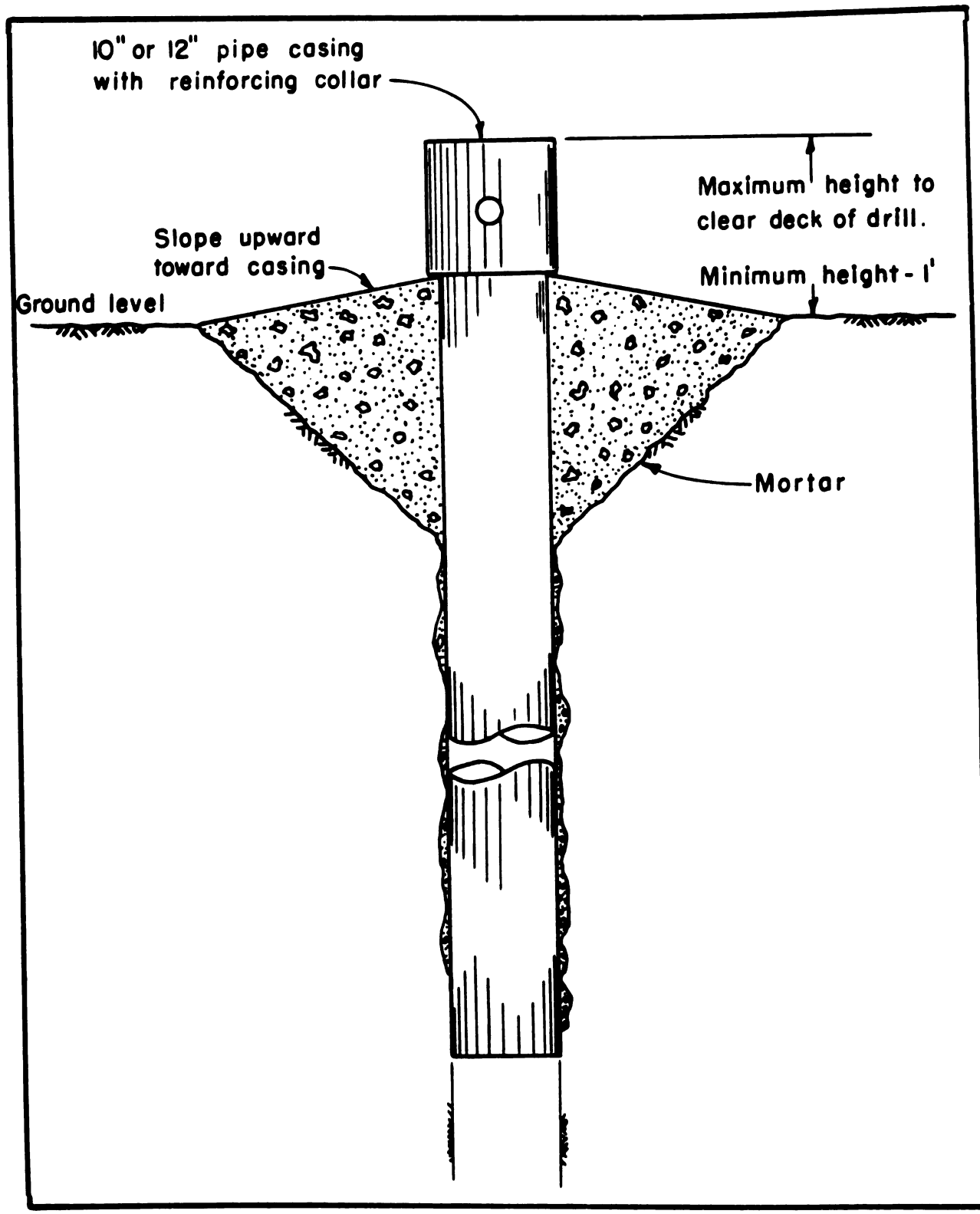

FIGURE 14. - Cross Section of Cement-Collared Churn-Drill Hole, New Cornelia Mine.

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Form 137 Revised—20 M

PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH — MINING DIVISION

DAILY CHURN DRILL REPORT

Drill No. ..... Shift ..... Level ..... Date ..... 195.....

Condition of drill at start of shift					
Condition of drill at end of shift					
Condition of sample splitter at start of shift					
Condition of sample splitter at end of shift					
Hole Number					
Stake Depth					
Started Drilling					
From — Depth					
Drilled to — Depth					
Footage Drilled					
Finished Hole — Time					
Formation — Hardness					
Drilling Time					
Moving Time					
Cleaning Hole — Time					
Number of Holes Cleaned					
Delay Time and Explanation					
Total Time					

SUPPLIES NEEDED	CHECK FOLLOWING PARTS LUBRICATED DURING SHIFT	✓
Cable Sling		
Shovel	Jack Shaft	
Measuring Rope	Sand Reel	
Cement Scoop	Bull Reel	
Cement	Spud Beam Shaft	
Casing	Spud Sheave	
Bits	Heel Sheave	
Jack Blocks	Pitman	
Jack Bars	Crankshaft	
Lubricants	Bell Crank	
Water Hose	Sand Reel Sheave	
Report Sheets	Crown Sheave	
Power Cable	Cats	
Bit Wrenches	Chain Block and Trolley	
Cribbing		
Crosses		
Screens		
Casing Bar		

BIT CHANGES

Hole No.	Depth	Dull Bit	Sharp Bit

CONDITION OF EQUIPMENT AND SUPPLIES

Sharp Bits	Dull Bits
Good Casing	B. O. Casing
Casing Driver	Grease Gun
Casing Puller	Tub Cover
Safety Belt	Measuring Stick
Swivel Wrench	Metal Stakes
Drill Line	Holes Staked
Circle Jack	Sample Equipment

Miscellaneous

REMARKS:

Driller .....

Helper .....

Driller Check To Verify If All Information Entered

FIGURE 15. - Daily Churn-Drill Report.

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PHELPS DODGE CORPORATION — New Cornelia Branch — MINING DIVISION

Churn Drilling Operations ..... 195 ..... Shift ..... Foreman

C.D. No.	Idle or Driller	Position		Footage	Shifts	Bits Used	Bits at Drill		REMARKS: Material, Supplies, Repairs Required on Machine
		Level	Hole No.				Sharp	Dull	
11									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
TOTAL									

DRILLS

C.D. No.	Idle or Driller	Position	Footage	Shifts	Bits Used	Bits at Drill		REMARKS: Material, Supplies, Repairs Required on Machine
						Sharp	Dull	
12								
28-L								
TOTAL								

MUD SCOW

C.D. No.	Idle or Driller	Position	No. of Holes Cleaned	Shifts	REPAIRS: Materials, Supplies, Repairs, Required on Machine
3					
TOTAL					

(Signed)_____

FIGURE 16. - Shift Report—Churn-Drilling Operations.

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PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH — AJO, ARIZONA

DAILY REPORT OF CHURN DRILLING OPERATIONS

Date.....

BLAST HOLE DRILLING

Drill No.	LOCATION		Type Material		TOOLS		Stroke	"A" SHIFT Foreman:			"B" SHIFT Foreman:			"C" SHIFT Foreman:			ALL SHIFTS		
	Level	Coordinates	Rock Class.	Hard-ness	Bit Diam.	Weight Lbs.	Length Inches	Driller	Drill Shifts	Foot-age	Driller	Drill Shifts	Foot-age	Driller	Drill Shifts	Foot-age	Drill Shifts	Foot-age	Bits Used
19																			
TOTALS								Ft./Shift			Ft./Shift			Ft./Shift					

DRILLING

Drill No.	Hole No.	Shift	Driller	Drill Shifts	Foot-age
28-L					
12					
TOTALS					

CLEANING HOLE

Drill No.	Level	Tools	Hole Diam.	"A" SHIFT Driller	Drill Shifts	No. Holes	"B" SHIFT Driller	Drill Shifts	No. Holes	"C" SHIFT Driller	Drill Shifts	No. Holes	ALL SHIFTS Drill Shifts	No. Holes Cleaned
3														
TOTALS														

SUMMARY	ALL AREAS Today	ALL AREAS Total — Month To Date	ALL AREAS Average Per Day	FANGLOMERATE AREA Today	FANGLOMERATE AREA Total — Month To Date	FANGLOMERATE AREA Average Per Day	OTHER AREAS Today	OTHER AREAS Total — Month To Date	OTHER AREAS Average Per Day
Blast Hole Drilling:									
No. of Crews Worked									
No. of Drill Shifts									
No. of Feet Drilled									
Feet per Drill Shift									
Prospect Drilling:									
No. of Crews Worked									
No. of Drill Shifts									
No. of Feet Drilled									
Cleaning Hole:									
No. of Crews Worked									
No. of Drill Shifts									
No. of Holes Cleaned — Mud Scows									
No. of Holes Cleaned — Total									
All Churn Drilling:									
No. of Crews Worked									
No. of Drill Shifts									

MISCELLANEOUS DRILLING

REMARKS

FIGURE 17. - Daily Report of Churn-Drilling Operations.

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Form 174 Rev.

Phelps Dodge Corporation, New Cornelia Branch
ORDER FOR MATERIALS AND SUPPLIES
Churn Drill Supply Report

Mining Division

Truck No. .....

Shift ..... Date .....

Drill No.	Hole Size	Level	At Drill			To Deliver						Picked Up		
			Sharp Bits	Dull Bits	Casing	Bits	Casing	Cement	Screens	Power Cable	Other Materials and Supplies	Bits	Casing	REMARKS:

Foreman

Driver

FIGURE 18. - Churn-Drill-Supply Report.

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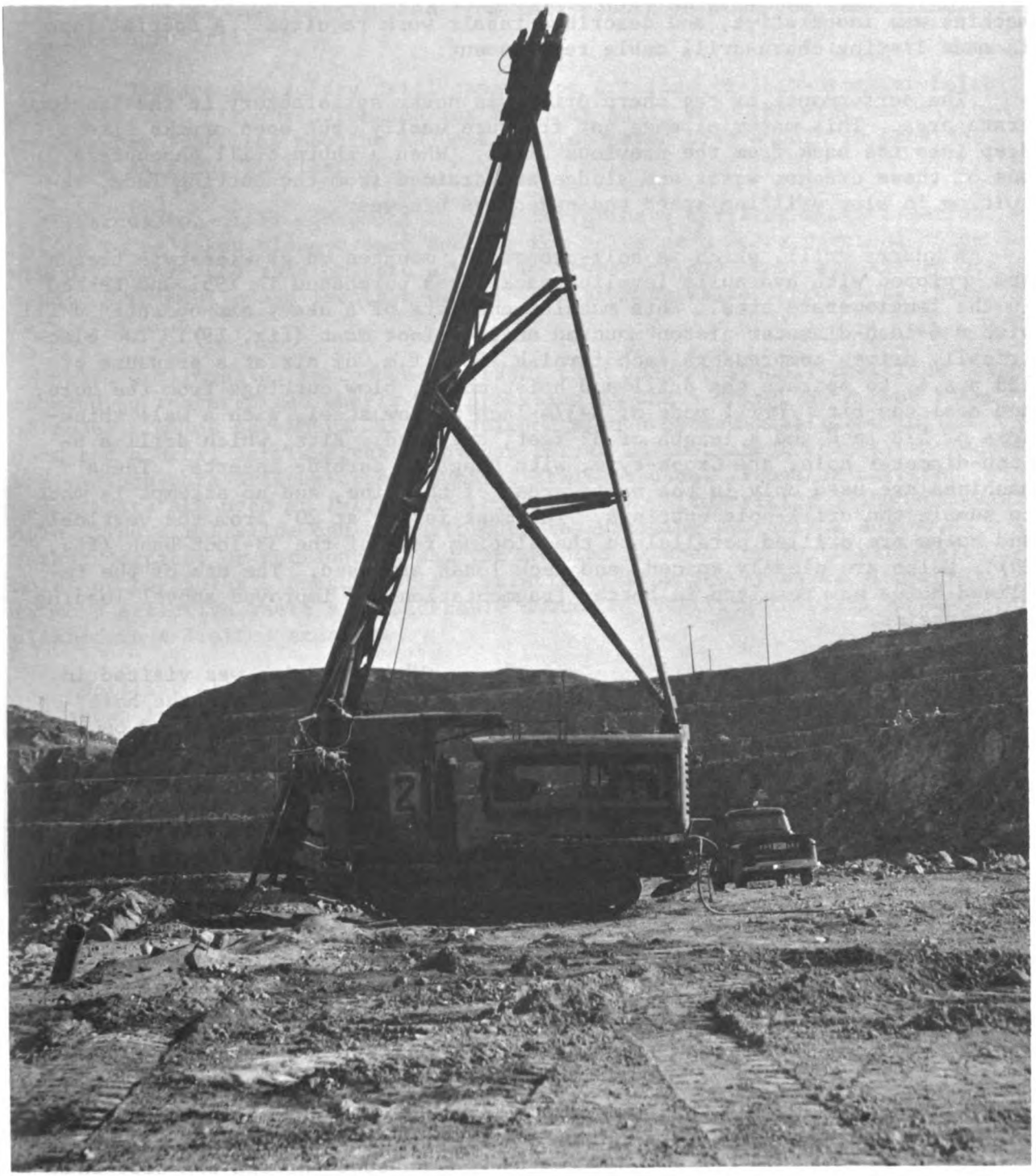

FIGURE 19. - Quarry Drill.

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report which lists drills that are unable to operate, tabulates hours that each machine was inoperative, and describes repair work required. A special report is made listing churn-drill cable replacement.

The performance of the churn drill was never satisfactory in the fanglomerate area. This material does not fracture easily, but open cracks extend deep into the bank from the previous blast. When a churn drill encounters one of these cracks, water and sludge are drained from the cutting face, resulting in slow drilling speed and excessive bit wear.

A quarry drill, which is self-propelled, mounted on crawler-type treads, and equipped with hydraulic leveling jacks, was purchased in 1951 and tested in the fanglomerate area. This machine consists of a heavy air-operated drill with a 6-inch-diameter piston mounted on a 40-foot mast (fig. 19). Two electrically driven compressors each furnish 756 c.f.m. of air at a pressure of 120 p.s.i. to operate the drill and hoist motor, blow cuttings from the hole, and cool the bit. Drill rods of 3-3/4-inch hollow steel, with a wall thickness of 5/8 inch and a length of 32 feet, are used. Bits, which drill a 6-inch-diameter hole, are Cross-type, with tungsten carbide inserts. These machines are used only in the waste areas of the mine, and no attempt is made to sample the drill-hole cuttings. The mast is set at 20° from the vertical, and holes are drilled parallel to the sloping face of the 33-foot bank (fig. 20). Holes are closely spaced, and deck loads are used. The use of the inclined holes has resulted in better fragmentation and improved shovel loading efficiencies.

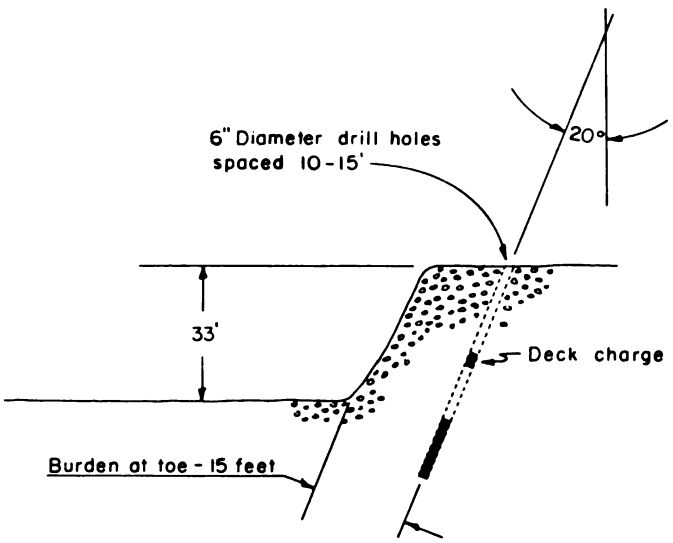

FIGURE 20. - Arrangement of Inclined Drill Hole in Fanglomerate, New Cornelia Mine.

When the mine was visited in December 1956, a "down the hole" type drill was being tested on these machines. Tests were favorable but not yet, complete, and the machine had not been in use long enough to provide statistical information for publication.

The "down the hole" drill is cased in a shell, smaller in diameter than the bit, and it is fastened on the working end of a 5-1/2-inch-diameter hollow drill rod. The bit is held in the drill with a retaining ring and moves in and out of the front head of the drill shell. Air is supplied through the hollow drill rod and is exhausted through the bit, thus cleaning the cutting face and cooling the bit. Exhausted air travels up the hole outside the tools and carries the cuttings to the surface. The backhead of the drill is provided with wear pads to enable the drill to ream its way out of a hole that may have caved. Additional rod sections can be added to the 40-foot starting rod turned by a separate air-powered motor.

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A daily quarry-drill report is made by the operating crew for each shift (fig. 21). Data are consolidated from this report in much the same manner as for the churn drill.

In 1956 a heavy rotary drill capable of drilling 12-inch-diameter holes with a tricone bit was purchased for trial at Ajo. When the mine was visited in December 1956, the machine had not been operated long enough to provide drilling data for publication.

Percussion-drill equipment is used for primary drilling where a narrow cut is to be taken along a bank and for toe holes used where vertical holes are drilled in the fanglomerate area. Two types of equipment assemblies are used: Drillmobile and Tractair drill. Performance is reported on the same form (fig. 22).

The Drillmobile, introduced in 1952, is a completely self-contained unit mounted on rubber-tired wheels and propelled by chain drive, at a road speed of about 4 miles per hour. It is equipped with a hydraulically controlled boom and a drill carriage that provides for an 18-foot steel change. A standard, 4-inch-bore drifter-type pneumatic drill is used. Tungsten carbide insert bits are used on 1-1/4-inch round steel rods to drill a 3-inch-diameter hole. The drill slide can be positioned for drilling at various angles, either vertical or horizontal, and the machine is used for short vertical holes or toe holes. Because of its relatively slow travel speed, this unit is more effective where a considerable amount of drilling is to be accomplished in a limited area.

Drilling efficiencies for various types of primary and secondary units are shown in table 1.

TABLE 1. - Drill efficiencies for the year 1956

Drills	Rock	Diameter of hole, inches	Total feet drilled	Feet per shift	Feet per bit use
Primary drill					
Quarry drill (inclined holes)	Fanglomerate	6	334,942	92.4	221.1
Drillmobile.....	do.	3	110,841	125.7	68.2
Churn drill.....	Monzonite	12	250,432	58.7	40.5
Secondary drill					
Jackhammers.....		1-5/8	150.977	88.1	
Travel drills.....		1-5/8	80,387	310.8	
Tractair.....		1-5/8	13,152	100.6	

Secondary Drilling and Breaking Boulders

Secondary drilling is a major problem in the New Cornelia mine. Before the adoption of self-contained, primary drilling units it was necessary to maintain air and water lines on all levels. After permanent air lines for the

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Form 812—30 M

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH — MINING DIVISION
DAILY QUARRY DRILL REPORT

Quarry Drill No. ..... Shift ..... Level ..... Date ..... 195.....

Hole No.					
Stake Depth					
Started Drilling					
From Depth					
Drilled to Depth					
Footage Drilled					
Finished Drilling Time					
Formation — Hardness					
Drilling Time					
Moving Time					
Delay Time					
Cleaning Hole					
Total Time					
Bit No.					

Condition of Drill at Start of Shift .....
Condition of Drill at End of Shift .....
Condition of Dust Collector at Start of Shift .....
Condition of Dust Collector at End of Shift .....

SUPPLIES NEEDED

Casing .....
Screens .....
Cribbing .....
Lubricants .....
Report Sheet .....
Bits .....
Drill Rods .....
Drill Rod Extensions .....
Drill Rod Couplings .....

COMPRESSOR OPERATING TIME

..... HRS.

COMPRESSOR ON LOAD THIS SHIFT

.....

CHECK PARTS LUBRICATED DURING SHIFT ✓

Compressor, Crankcase .....
Air Line Lubricator .....
Cats .....
Air Filters .....
Drill Guide .....
Feed Motor .....
Propelling Motor .....
Hydraulic Pump Motor .....
Air Hoist Motor .....
Hydraulic Pump Tank .....
Dust Collector .....
Jacks .....
Feed Chain .....
Feed Chain Sprockets .....

CONDITION OF BITS

Bit No.	Remarks

CONDITION OF EQUIPMENT AND SUPPLIES

Hand Tools ..... Endless Chain .....
Oil Can ..... Cable Tongs .....
Tubing Tongs ..... Grease Gun .....
Pull Lift ..... Safety Fence .....
Safety Belt ..... Sample Equip. .....
Safety Clamp ..... Holes Staked .....

REMARKS: .....

Driller: .....

Helper: .....

Delay Time and Explanation: .....

No. of Holes Cleaned: .....

FIGURE 21. - Daily Quarry-Drill Report.

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Form 108 Rev. — 5 M

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
MINING DIVISION

Primary ☐ Check ✓
Secondary ☐

DAILY AIR DRILL REPORT

Shift Date 19 Foreman:

Setup No.	1	2	3	4	5	6	7	8
Type of Drill								
Drill No.								
Position: Ahead Shovel No.								
Behind Shovel No.								
Crew: (Payroll Number)								
Number of Holes Drilled								
Total Footage Drilled								
Drilling Time — Hours								
Delay Time — Hours								
Explanation — Delay Time								
Type of Drilling: Boulders								
Track Grade								
Hard Pit								
Toe Holes								
Crest Holes								
Air Supply: Compressor No.								
Hours Used								
Air Lines								
Tungsten Carbide Insert Bits: Bits Issued Start of Shift—Nos.								
Bits Ret. at End of Shift—Nos.								
Condition of Drill:								
Condition of Compressor:								
Supplies Needed:								
Cond. of Air and Water Lines:								
Shifts of Drilling Remaining:								

REMARKS:

FIGURE 22. - Daily Air-Drill Report.

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primary drills were eliminated, they were not justified for secondary drills. A compact, mobile jackhammer unit was designed, with all required equipment mounted on one vehicle. This unit consists of a 210-c.f.m. rotary compressor, water tanks, and hose reels mounted in a convenient position on the bed of a 2-ton truck. The unit is operated by two men, each operating a jackhammer (fig. 23).

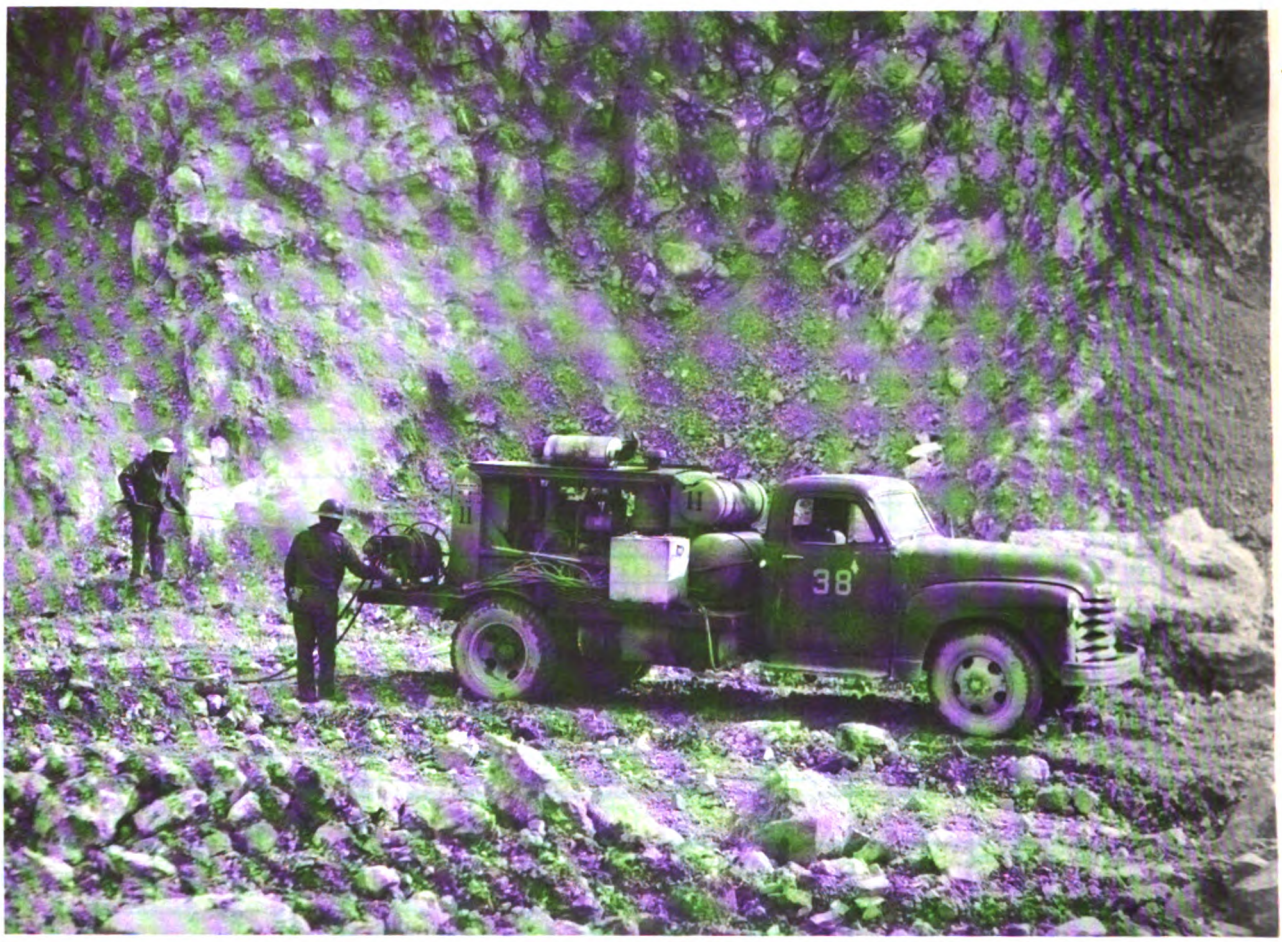

FIGURE 23. - Jackhammer Unit.

A self-contained drill unit was required for small jobs that were intermediate between secondary and primary drill, and an industrial tractor-compressor unit with a slide-mounted 2-1/2-inch drill on the rear was purchased (fig. 24). It is more effective where 3- to 6-foot holes are required, for example, to drill humps in a railroad grade or a hard toe in the shovel pit. This machine is used in secondary drilling only.

In the fanglomerate area and, to a lesser extent, in the hard monzonite area many large boulders occur high up in the face of the bank. This is particularly true after the shovel has taken the first or splatter cut.

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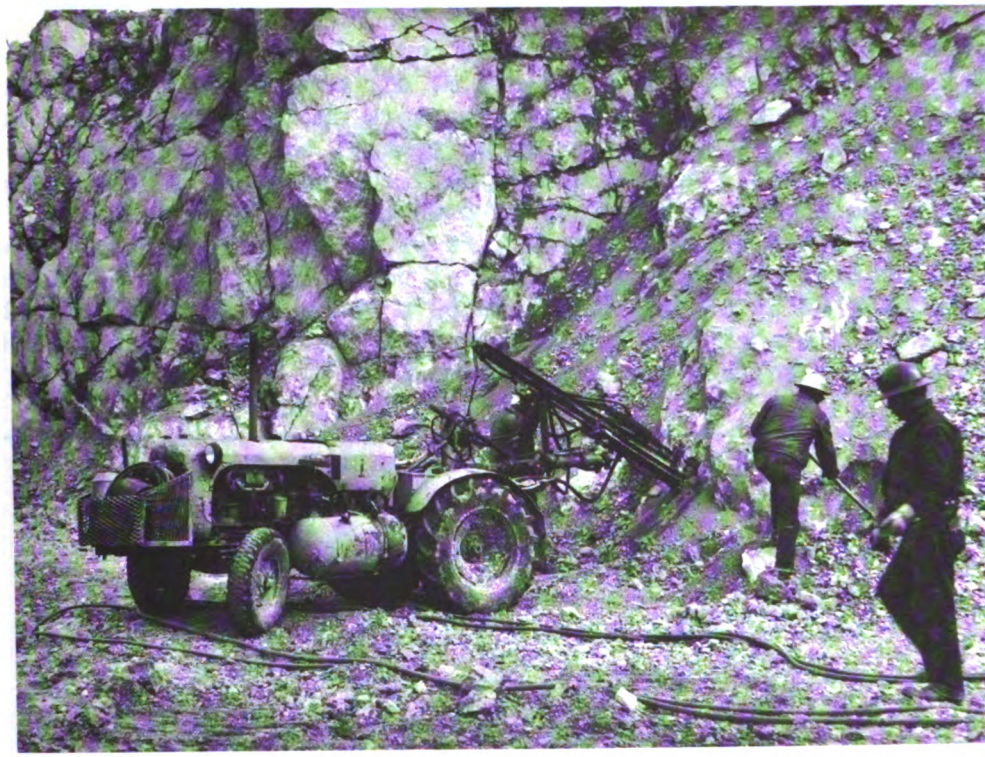

FIGURE 24. - Tractor-Compressor Unit.

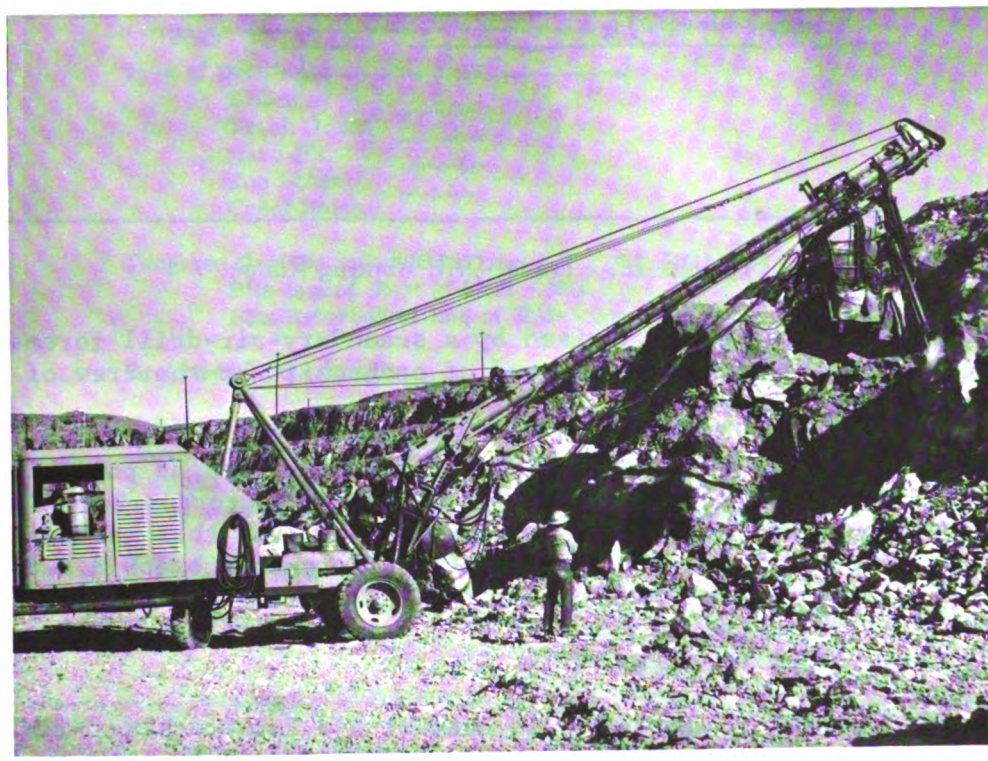

FIGURE 25. - Travel Drill.

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A unit called a "Travel Drill", purchased for this work (fig. 25), is powered by a diesel motor which drives a 230-c.f.m. air compressor. It is mounted on three wheels; two front wheels drive and steer, while an underslung swivel wheel supports the rear. A 3-foot square control basket is suspended from a carriage that slides on a 40-foot boom. All controls are in the basket or control chair, which can be moved up or down the boom by the operator. The drill slide is mounted as an integral part of the carriage in such a way that holes can be drilled through a wide lateral range (fig. 26). By raising or lowering the boom or by moving the operator's basket along the boom the machine can drill as much as 33 feet above the toe. The efficiency of the machine is higher than that of the jackhammer.

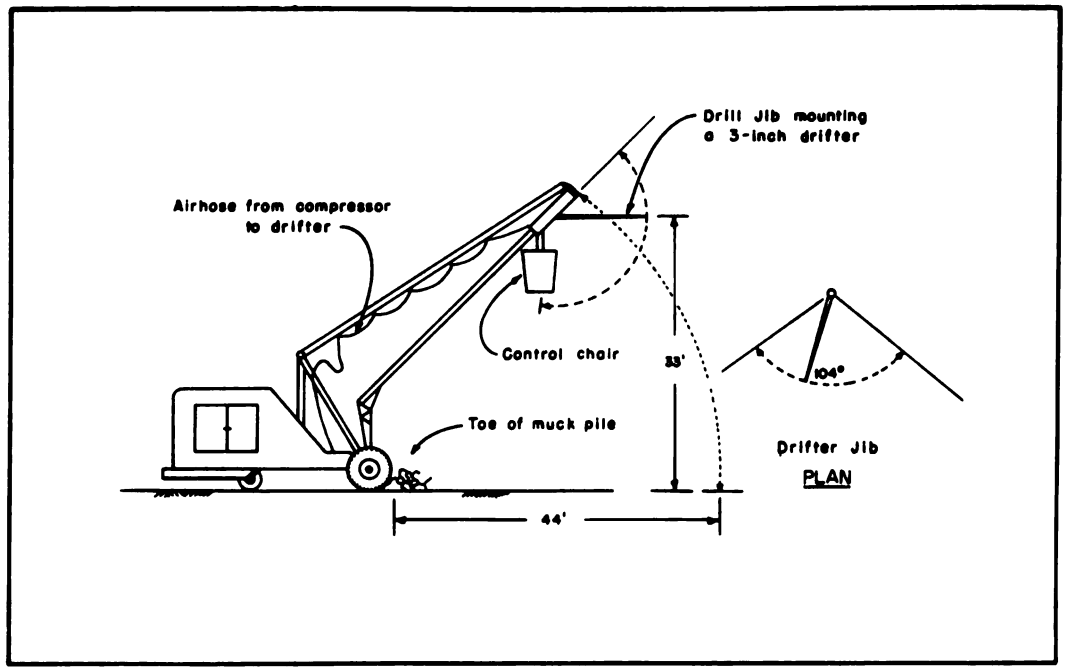

FIGURE 26. - Travel-Drill Working Range.

Secondary drilling is supervised by a secondary-air-drill foreman. A separate report is submitted at the end of each shift by the crew of each drilling unit (fig. 27).

Secondary drill holes are loaded and blasted as soon as possible after they are drilled. All charges are detonated with primacord. Some isolated boulders are broken by "adobe" or plaster blasting, but this method is avoided when possible. The secondary blasting foreman submits a report that accounts for all secondary blasting by area. All primary blasts are numbered, and all secondary blasting in the area of a primary blast is referred to the original primary blast by number (fig. 28).

A "skull breaker" or drop ball is used at Ajo for breaking boulders. The cast-steel ball, weighing 5 to 6 tons, is maneuvered by a 40-ton, rubber-tired crane. This piece of equipment has been particularly efficient where

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PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
Mining Division
Daily Secondary Air Drill Report

SHIFT_____ DATE_____19___ FOREMAN:_____

SETUP NO._____

Type of Drill_____

Drill No._____

Position:
Ahead Shovel No._____
Behind Shovel No._____

Crew: Name:_____Payroll No._____

Number of Holes Drilled_____ Total Footage Drilled_____

Actual Drilling Time - Minutes_____

Delay Time - Minutes_____

Explanation - Delay Time _____
_____
_____

Type of Drilling:
Boulders _____
Track Grade _____
Hard Pit _____
Toe Holes _____
Crest Holes _____

Tungsten Carbide Insert Bits:
Bits Issued Start of Shift - Nos._____
Bits Returned at End of Shift - Nos._____

Broken Steels - Length_____

Condition of Drill:_____ Condition of Compressor_____
Condition of Water Lines_____
Supplies Needed:_____
Shifts of Drilling Remaining_____

Remarks:

FIGURE 27. - Daily Secondary Air-Drill Report.

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PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
Mining Division

DAILY SECONDARY BLASTING REPORT

SHIFT_____ DATE _____ Foreman_____

Level	Primary Blast No.	No. of Boulders Drilled	No. of Boulders Adobed	No. of Drill Holes Tr. Grade	No. of Drill Holes Crest	No. of Drill Holes Toe	Powder Used

REMARKS:

FIGURE 28. - Daily Secondary Blasting Report.

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large numbers of boulders are grouped in a limited area. An average of 1-1/2 minutes is required to break each boulder after the drop ball crane is in position.17/ Drop-ball breaking has replaced adobe blasting and secondary boulder drilling to a great extent and has the advantage of less interference with other operations. Two of these units (fig. 29) are in operation at the New Cornelia mine.

Bit-Sharpening Shop

Rods for percussion drilling are fabricated out of 1-1/8-inch- and 1-inch-diameter round, hollow steel purchased in bulk. Lugged shanks are forged, and pins for Timken bits are upset, threaded, and heat treated in the drill shop. The shop is equipped to hot-mill carbon-steel bits; but at present only carbide-insert bits are used, and these are ground when corners become rounded. Sharpening data for various sized percussion-drill bits are shown in table 2.

Purchased, blank churn-drill bits are heated in an oil-furnace, and then sharpened on a No. 12 bit-dressing machine. Bits are handled with an electric traveling crane suspended from an I-beam track overhead. Sharpened bits are hauled to the drill location by a truck that is equipped with a short boom and power-takeoff hoist. The 12-inch churn-drill bits are sharpened an average of 80 times and drill approximately 40.5 feet per bit use.

A complete set of fishing tools is in stock for the recovery of "stuck" tools. In spite of all efforts for recovery, bits from the churn drill, quarrymaster drill, and rotary drill are sometimes lost. When the bits or tools cannot be recovered before blasting, a special report, "Initial Report of Lost Drilling Tools", is made, giving the exact location of the lost tools as determined by the engineering department (fig. 30). A search is made as the shovel digs through the reported position, and the item is recovered. All large bits and tools must be removed from ore because it is dumped directly into the 54-inch primary crusher, and a large piece of steel, such as a churn-drill bit, would damage this machine.

TABLE 2. - Tungsten carbide bit-sharpening data (1956)

Size of bit inches	Average number of sharpenings	Total feet drilled per bit
1-5/8.....	6	590
3.....	5	368
6.....	14	2,934

Blasting Practice

Because some of the rock types found at the New Cornelia mine are particularly difficult to break, the selection and use of explosives have primary importance. During 1956 the average break was 3.41 tons of material per pound of powder. In the fanglomerate area 2.58 tons per pound was broken, and in all other parts of the mine average was 3.90 tons per pound. The 6-inch

17/ Work cited in footnote 15 (p. 17).

533841 O—60——6

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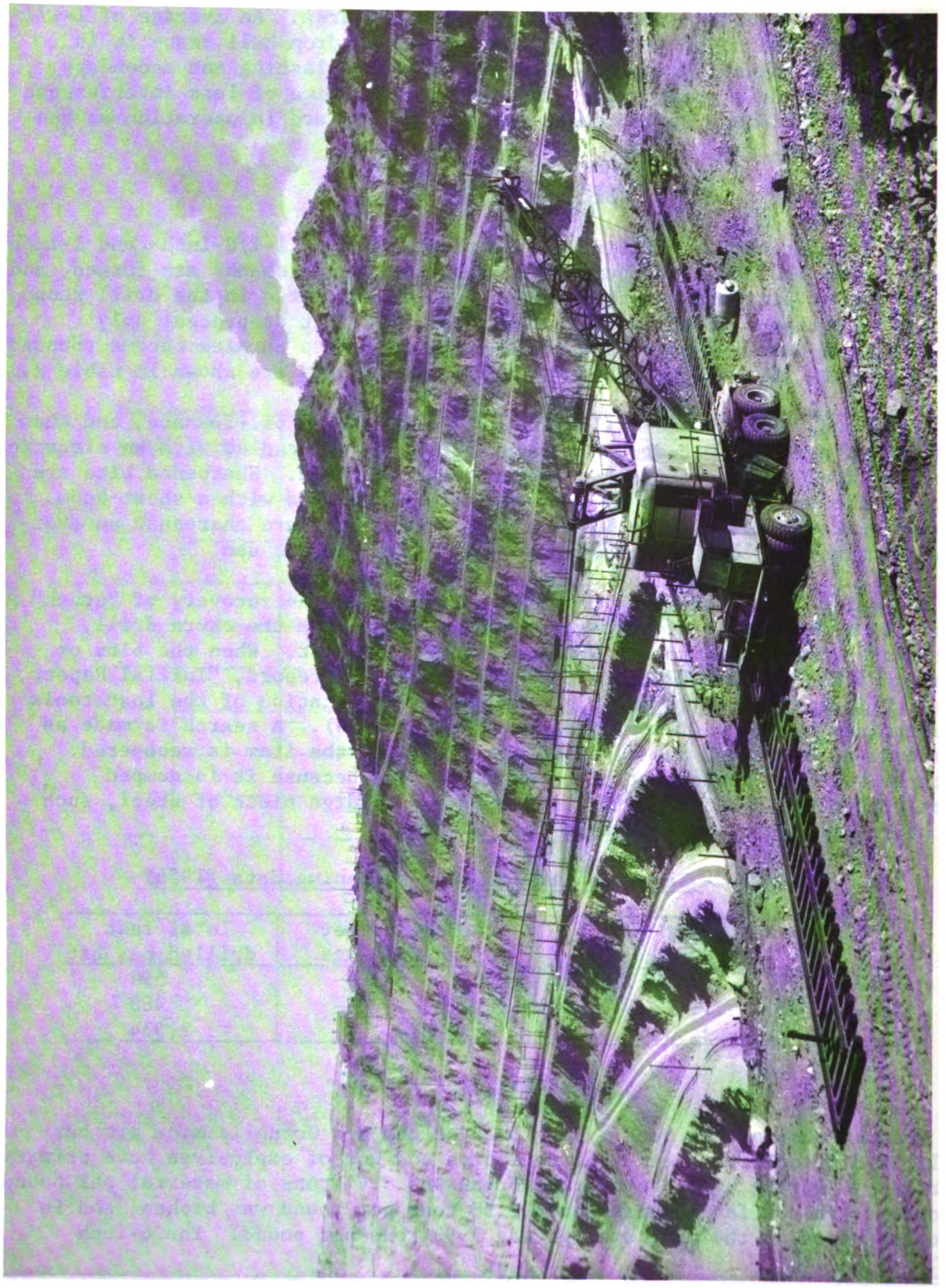

FIGURE 29. - Drop Ball and Crane.

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Report No. _____

INITIAL REPORT
OF
LOST DRILLING TOOLS

Date--- _____ Shift _____

Description of Item Lost _____

Number or Other Identification _____

Drill Number _____

Depth of Hole _____

Level _____

Hole Number _____

Coordinates of Hole _____ _____

Remarks: _____

_____

_____

Signed _____ Churn Drill Foreman *

Signed _____ Asst Drilling & Blasting Foreman **

* One copy to Assistant Drilling and Blasting Foreman

** Three copies: General Mine Foreman, Ore Control Engr., D & B File.

FIGURE 30. - Initial Report of Lost Drilling Tools.

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quarry drill holes broke 13.5 tons per foot of hole in the fanglomerate area, whereas the 12-inch churn-drill holes broke 67.0 tons per foot in all other parts of the mine.

All primary drill holes are numbered as they are drilled. The numbered holes are located by transit and stadia and plotted on the mine map by the engineering department. As soon as possible after the holes are drilled, the first part of a form called a "Powder Loading Sheet" (fig. 31), including columns I, H, C, T, D, and B, is completed by the engineering department and submitted to the drilling and blasting foreman.

Before loading operations begin, the primary powder boss measures the actual loading depth and the amount of water in the holes. The drilling and blasting foreman or the primary blasting foreman then examines each hole and determine the loading factor, total powder charge, type of powder, and whether or not the hole is to be deck loaded. When this information has been entered on the powder-loading sheet, the drilling and blasting foreman computes the amount of powder and primacord required for the blast.

Explosives are delivered to the loading zone as needed. All loading operations are planned so no explosives are left in the ground longer than necessary, and all loaded holes must be stemmed the same day. Tailings from the leach plant are used for stemming. These tailings (originally crushed to minus 3/8-inch mesh) are loaded in railroad cars, hauled to the mine, and dumped into a conveniently located bin. They are drawn from the bin into a truck with a Dumpcrete body, hauled to the loading operation, and fed to the hole through a conveniently controlled chute on the end of the truck body.

All primary blastholes are double primed. Vertical holes are primed with two strands of wire-countered primacord, and toe holes are primed with two strands of reinforced primacord. A rock is tied to the primacord, which is then lowered to the bottom of the hole. Next the powder is dropped in the hole. Gelatin primers may be placed in the bottom of the hole, or, where several boxes of gelatin are necessary to load the wet portion of a hole, the first primer is placed on the bottom, and the second about half way up in the gelatin column. In completely dry holes, bag powder only, without gelatin primers, is loaded after the wire-countered primacord leads, weighted with rocks, are lowered to the bottom of the hole.

No primer cartridge is placed in deck loads, but precaution is taken to have the powder in contact with the primacord. Deck loads are small explosive charges that are placed in the upper part of a blast hole to aid fragmentation (fig. 20). They are separated from the main charge by several feet of stemming. A minimum of 1 foot in any size hole is required for any deck charge. Either gelatin or free running powder is used, depending on whether the hole is wet or dry.

Primacord is used to detonate all percussion-drill holes. Caps, either fire or electric, are not used in the hole. A primer cartridge is made as illustrated in figure 32, inserted into the hole first with bottom end down, and pressed firmly in place. Additional cartridges, if necessary, are pressed in place. Horizontal holes are stemmed with paper-wrapped cartons of stemming.

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Form 104 — Revised

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
MINE DIVISION

POWDER LOADING SHEET

Date 7-22-55
Shovel No. 17
Level 1670
Blast No. 518

I=Interval (feet)
H=Depth to shovel grade (feet)
C=Distance hole to crest (feet)
T=Distance hole to toe (feet)
D=Theoretical loading depth (feet)

B=Total burden (cu. yds.)
A=Actual loading depth (feet)
F=Loading factor (lbs. powder per cu. yd. of burden)
P=Powder rise of bottom charge (feet)
S=Feet of Stemming above last deck charge

Hole No.	Dia. In.	I	H	C	T	D	B	A	F	Boxes of Powder					P	S	Depth of Water	
										Bottom		Deck		Total			Before Cleaning	After Cleaning
											LDX	1st	2nd					
41X	12	26	40	9	37	53	1117	52		5	17½			22½	20	32	1/2	
42		24½	39	11	37	51	1051	52		5	16			21	19	33	1/2	
43		26	39	11	32	51	992	51		5	15½			20½	18	33	1/2	
44		26½	40	14	35	53	1185	51		21				21	21	30	6	
62	12	28	41	7	31	54	1018	51	1#	20½				20½	20	31	7	
63	12	29½	41	9	27	54	995	52	1#	20				20	20	32	10	
64	12	29	41	9	30	54	995	56		17½				17½	18	38	12	
65	12	30	40	10	28	53	1043	54		21				21	21	33	7	
66X	12	26	40	10	25	53	830	50		16½				16½	16	34	6	
TOTAL		715	1058	292	836	1394	28809	1358		492	49			541	532	826	324½	
AVERAGE		27½	40.7	11.2	32.2	53.6	1108.0	52.2		18.9	1.9			20.8	20.5	31.8	12.5	
										12# CD Holes							26	
										FOOTAGE							1394	
										+ 2' ADJ							52	
										TOTAL							1946	
										AV. DEPTH							55.62	
										PRIMACORD			7300 WIRE BOUND					
													800 PLAIN					
													8100					

Remarks:

NOTE: Sketch Hookup on Reverse Side of Sheet.

POWDER BOSS:

POWDERMEN:

HELPERS:

FIGURE 31. - Typical Powder-Loading Sheet, Sulfide Area.

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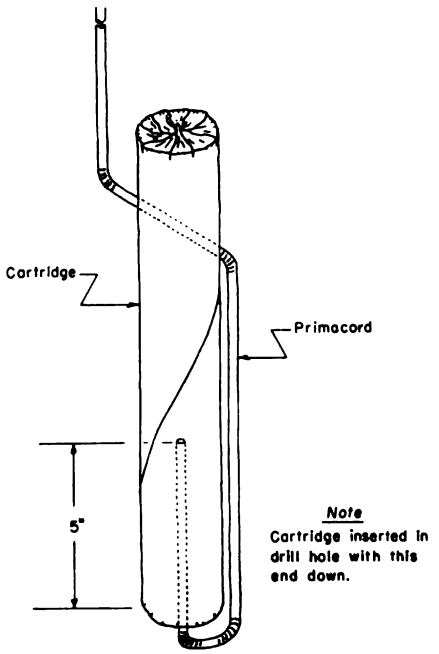

FIGURE 32. - Method of Connecting Primacord to Primer Cartridge.

After all blastholes have been loaded, stemmed, and inspected by the primary loading foreman, they are tied to a main trunkline of plain primacord that extends 100 feet beyond the last blasthole for quarry-drill, or 60 feet for churn-drill holes. When a blast contains both toe holes and vertical primary holes, the toe-hole charges are tied to the trunk primacord so that they will fire first. If the length of the blast exceeds 300 feet, jumpers are used as illustrated in figure 33. When the blast is ready to fire, blasting wire is strung from the end of the primacord to a blasting machine, a cap is hooked to the wire, and the circuit is tested. The cap is placed on the primacord, and after safety measures have been checked, the blast is fired (figs. 34, 35, and 36).

Immediately after a blast is fired, a blast report is made by the mining division based on information extracted from the powder-loading sheet. A copy of this form is sent to the engineering department, the material broken is estimated, and the form is returned to the mining department. The completed forms for a typical blast in sulfide area are shown on figures 31, 37, and 38. A typical powder-loading sheet for a blast in the fanglomerate area is illustrated by figure 39.

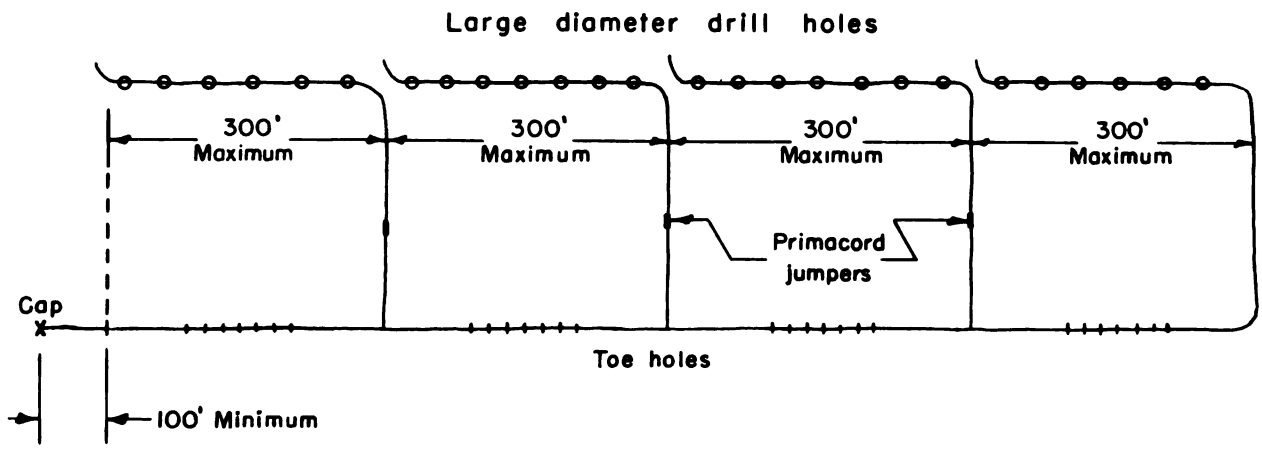

FIGURE 33. - Diagram of Primacord Arrangement When Both Bankholes and Toeholes Are Fired at the Same Time.

The cleaned-up face of a bank in fanglomerate, as shown in figure 40, illustrates the fact that virtually no break beyond the drill hole is realized in this area. In most instances the inclined holes from the last blast are clearly visible after the bank has been cleaned.

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FIGURE 34. - Fanglomerate Bank Ready to Blast.

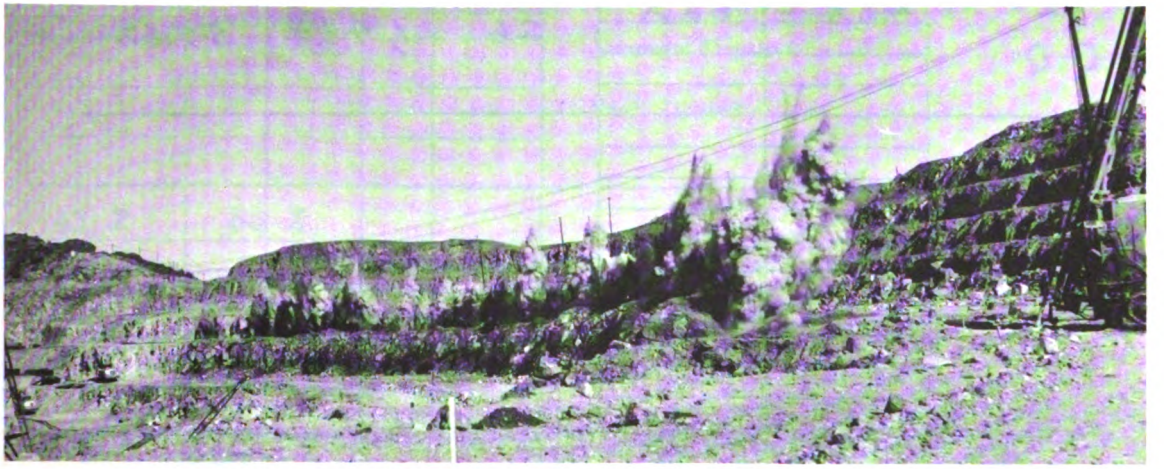

FIGURE 35. - Blast in Fanglomerate Bank.

FIGURE 36. - Broken Material After Blast in Fanglomerate Area.

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Form 186 Rev.—8M

PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH

MINING DIVISION

518

BLAST REPORT

BLAST No. LEVEL 1620 DATE SHOT 7-22-55

COORDINATES: FROM To

Class of Holes	Series Shot From	Series Shot To	Number of Holes	Total Feet Drilled	Average Depth
12" C.D	41X -	66X	26	1,446	55.62

Boxes of 10X12 Quarry Spec.	Powder	436
Boxes of 5X24 "	Powder	56
Boxes of LOX Bag	Powder	49
Boxes of	Powder	
Total Boxes of Powder		541
Total Pounds of Powder		27050
Feet of Prima Cord		8,100
Number of Caps		1
Truck Loads of Tailings		5
Number of Men		7
Hours Worked		8
Gang Boss		

Remarks:

7300 WB
800 P

FIGURE 37. - Blast Report (by Mine Division).

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Form 185—2M

PHELPS DODGE CORPORATION

ENGINEERING DEPARTMENT
NEW CORNELIA BRANCH

BLAST REPORT 17 Shovel

BLAST NO 518 LEVEL 1620 DATE SHOT July 22, 1955

COORDINATES: FROM M 1/8 - 2 1/4 TO 0 7/8 - 3 3/4

Series Shot From	Series Shot To	Class of Holes	
			No. of A. D. H.'s
			Average Depth
			Feet Drilled
41 X	66 X		
			No. of C. D. H.'s 26
			Average Depth 55.6
			Feet Drilled 1446
		12"	Tons 109,000 T/# 4.0 T/Ft. 75.4
			Total No. Holes
			Average Depth
			Total Feet Drilled
			Boxes Powder 541

REMARKS:

Average Interval - 27.5

J. E. O.

FIGURE 38. - Blast Report (by Engineering Department).

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Form 194 — Revised

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
MINE DIVISION

POWDER LOADING SHEET

Date 7 - 6 - 55
Shovel No. .....
Level 1858
Blast No. 209

I=Interval (feet)
H=Depth to shovel grade (feet)
C=Distance hole to crest (feet)
T=Distance hole to toe (feet)
D=Theoretical loading depth (feet)

B=Total burden (cu. yds.)
A=Actual loading depth (feet)
F=Loading factor (lbs. powder per cu. yd. of burden)
P=Powder rise of bottom charge (feet)
S=Feet of Stemming above last deck charge

Hole No.	Dia. In.	I	H	C	T	D	B	A	F	Boxes of Powder: Bottom LDX	Deck 1st	Deck 2nd	Total	P	S	Depth of Water: Before Cleaning	After Cleaning
30 C	6	12	19	11	18	25	138	31		3			3	15	16	0	
31	6	13½	19	12	19	25	164	31		3			3	15	16	0	
32	6	15	20	10	17	26	142	30		3			3	15	16	0	
33	6	15½	21	11	14	26	166	31		3			3	15	16	0	
34	6	15½	21	10	13	26	155	31		2	½		2½	10	21	0	
35	6	15½	22	8	12	28	143	31		2	½		2½	10	21	0	
36	6	16	23	7	13	28	157	33		2	½		2½	10	23	0	
37	6	16½	24	7	12	29	159	35		1½	½		2	8	27	0	
38	6	17	25	6	14	32	181	33		2½	½		3	13	20	0	
39	6	16½	27	12	21	36	218	35		2½	½		3	13	22	0	
40 C	6	16	28	5	15	37	195	35		2	½		2½	10	25	0	
TOTAL		169	249	99	168	318	1818	356		26½	3½		30	134	222		
AVERAGE		15.4	22.6	9.0	15.3	28.9	165.3	32.4		2.4	.32		2.7	12.2	20.2		

Remarks:

POWDER BOSS:

POWDERMEN:

HELPERS:

NOTE: Sketch Hookup on Reverse Side of Sheet.

FIGURE 39. - Typical Powder-Loading Sheet, Fanglomerate Area.

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FIGURE 40. - Face in Fanglomerate Area, Showing Remains of Blasted Drill Holes.

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FIGURE 41. - Truck-Mounted Churn Drill for Cleaning Blastholes.

It often is necessary to clean churn-drill holes before they are loaded. A light churn drill has been mounted on a standard industrial truck for this job (fig. 41).

Powder Magazine

Blasting powder is received at Ajo in standard railroad cars; these are routed to one of three powder magazines, with a combined capacity of 800,000 pounds of explosive, immediately after arrival. The magazines are built with adobe brick walls 18 inches thick. Doors are bulletproof, and the magazine is surrounded with an embankment and fence. Powder is transported from the freight car into the magazine and from the magazine to a mine truck by a system of nonsparking roller conveyors.

An attendant is in charge of the magazine. No powder is released without a written order signed by the drilling and blasting foreman (fig. 42). An accurate inventory is maintained at all times. Blasting caps, primacord, and fuse are stored at a separate location.

Types of explosives normally used at the New Cornelia mine are shown in table 3.

Shovel Loading

During 1956 an average of 31,503 tons of ore and 45,184 tons of waste was loaded per operating day. Overall performance figures for the year include 3,845 tons per shovel shift, 116,253 tons per set of dipper teeth, and 214,902 tons per hoist cable. Thirteen full-revolving, electrically driven shovels were in operation during 1956 (fig. 43). Of these, 10 shovels were equipped with a five-tooth, 6-cubic-yard dipper; two were equipped with a 7-cubic-yard dipper; and one was equipped with a six-tooth, 9-cubic-yard dipper. All shovels were equipped with fabricated steel (alloy) booms and outside dipper sticks. Separate efficiency figures on the different-size shovels are not available for publication.

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Form 173 1M

PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH — MINE DEPARTMENT

DAILY POWDER ORDER AND INVENTORY

Date..... 19.....

Level	Foreman	No. Boxes	Kind	Picked Up		Remarks
				No. Boxes	Kind	

DAILY TEMPERATURE

INVENTORY — 2:00 P. M...... 19.....

Kind of Powder	Magazine No. 2	Magazine No. 1	Total on Hand	Total Out This Month	Remarks

PRIMACORD

In.....

Out.....

_____

Powder Foreman

FIGURE 42. - Daily Powder Order and Inventory.

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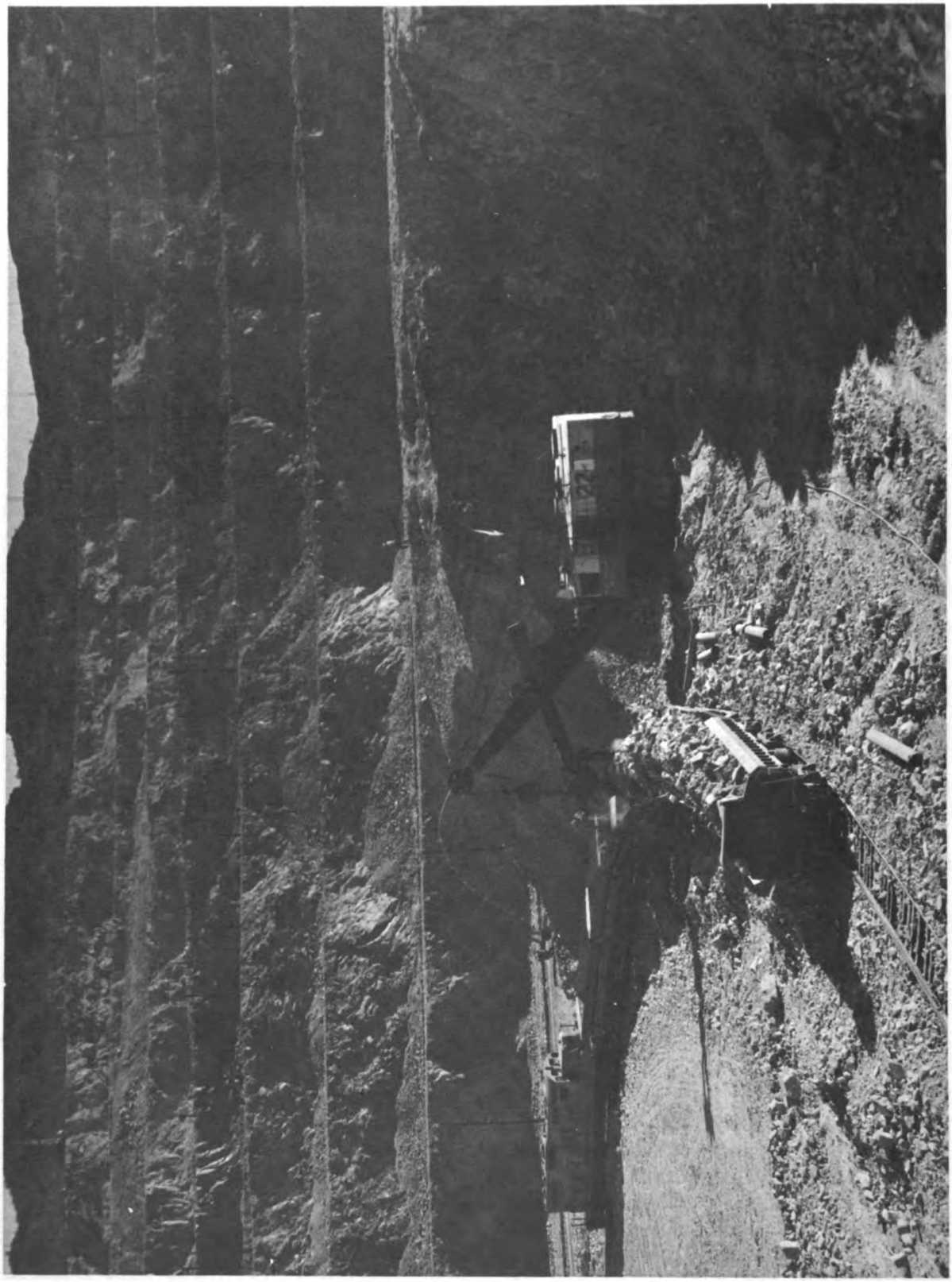

FIGURE 43. - Electric Shovel Loading From a 40-Foot Bank.

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TABLE 3. - Explosives normally used at New Cornelia mine for primary blasting

Explosive name	Cartridge size (dia. and length), inches	Cartridges per case	Weight per case	Water resistance	Consistency
Quarry Special 60 percent.....	8 x 18	1	50	Very good	Fairly plastic.
Do.....	10 x 12	1	50	do.	Do.
Do.....	5 x 24	2	50	do.	Do.
L.F. Special Gelatin 60 percent	4 x 8	9	50	do.	Plastic.
Do.....	1-1/4 x 12	Approx. 65	50	do.	Do.
LDX-750 Bag Powder 70 percent.....	12-1/2# Bag	4 bags	50	Poor	Granular free running.

An electric shovel crew consists of an operator, an oiler, and a pitman. The operator is in charge of the shovel operation, subject to instructions by the shift foreman. With the assistance of a pit repairman, he makes or directs minor repairs, such as changing hoist cables, turning dipper teeth, or moving the shovel. The operator determines whether he is loading ore or waste from markers placed along the track and makes a daily report noting locomotive numbers and number and type of cars loaded (fig. 44). Banks are sprinkled with water from sprays on point of boom or by a bankman to settle the dust. A daily shovel lineup (fig. 45) is made to help the shift foreman select the shovels to be operated, and production is reported on a shift report (fig. 46).

From the powerhouse near the smelter electric current is delivered to the mine at 13,000 volts. Here it is reduced at a transformer station and carried around the pit on a high line at 4,000 volts. At various convenient points around the pit, feeder lines run into the pit on poles placed near the crest of the banks. Cables carry the power to a locked switch house near the foot of the pole. From this switch house the current is carried to the shovel by insulated power cables orange in color for easy identification and safety. The 800-foot lengths of 1-3/4-inch cable have connecting sockets so that two or more lengths can be fastened together if necessary. The cable is constructed with three No. 3 wires for conductors and three No. 9 wires for the ground system. A special truck with a power-driven reel (fig. 47) is used to pick up and distribute cable. The reel can be lifted from the truck and replaced with an empty spool if the cable is to be stored.

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Form 114-A — 20M

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
MINING DIVISION
DAILY SHOVEL REPORT

Shovel No. ..... Shift ..... Level ..... Date .....

TRAINS							DELAYS				EXPLANATION OF DELAYS
Locomotive Number	Arrival at Shovel	Leaving Shovel	Loading Time	Cars Loaded 30 Yard	Cars Loaded 20 Yard	Ore or Waste	Drilling and Blasting	Mechanical	Electrical	Train Service	Over 5 minutes — Give detail. Less than 5 minutes — Charge to loading time.

Condition at Beginning of Shift
- Pit .....
- Shovel .....
- Water and Air Lines .....
- Power Cable .....

Pitman .....
Oiler .....
Operator .....

Moved to Shovel No. ..... at ..... M. Acct.

Relieved at ..... M.

FIGURE 44. - Daily Shovel Report.

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PHELPS DODGE CORPORATION – New Cornelia Branch

MINING DIVISION

DAILY SHOVEL LINE - UP

From B Shift..... to B shift.....

○ — Work □ — Spare X — B. O.

ORE

B Shift		C Shift		A Shift	
Shovel No.	Grade % Cu.	Shovel No.	Grade % Cu.	Shovel No.	Grade % Cu.
14		14		14	
15		15		15	
16		16		16	
17		17		17	
18		18		18	
19		19		19	
20		20		20	
21		21		21	
22		22		22	
23		23		23	
24		24		24	
25		25		25	
26		26		26	
Av'ge		Av'ge		Av'ge	

WASTE

Shovel No.	Shovel No.	Shovel No.
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26

REMARKS: .....

FIGURE 45. - Daily Shovel Lineup.

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Form 127 — SM

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH — MINING DIVISION

Mine Operations ..... 195 ... Shift ..... Foreman

Weather .....

Shovel No.	Level	Idle or Runner	Cars Loaded		Ready to Operate		Kind of Digging	Shifts Ground Broken	Rail Lengths Track	Delays (in minutes)			
			Ore	Waste									
			30-yd	30-yd	Ore	Waste				D & B	Mech.	Train	Other
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
Total													

SHOVELS:

No. 14

No. 15

No. 23

No. 24

No. 25

No. 26

TRAINS: (Including Locomotive Failures and Derailments)

CRUSHERS:

Tons Ore Loaded: Tons per Shovel Shift: Car Factor:

DUMPS:

— Rail Length Dumping Space

No. 2 — Rail Length Dumping Space

No. 3 — Rail Length Dumping Space

No. 4 — Rail Length Dumping Space

No. 5 — Rail Length Dumping Space

OTHER:

FIGURE 46. - Mining Operations Shift Report.

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FIGURE 47. - Special Truck Used to Pick Up and Distribute Power Cable.

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Train Haulage[18/]

Ore and waste are hauled by 18 diesel-electric or trolley electric locomotives, each pulling seven-car trains. About 115 cars with 30- or 32-cu.-yd. capacity are in use, and the car factor is about 60 tons. In 1956 the average ore haul was 3.230 miles with a lift of 368 feet, while the average waste haul was 2.818 miles with a lift of 229 feet. On January 1, 1957, 41.4 miles of track was in use. Bonded and electrified main-line track is laid with 115-pound rail, with a maximum curvature of 15°. Bench, yard, and dump tracks are laid with 90-pound rail and generally are not electrified. Trolley electric locomotives have auxiliary diesel units for use on track that is not electrified.

Ore haulage from mine to crusher is over a spiral main-line track with a ruling grade of 3 percent adverse to the load. The principal entrance is at the northeast corner, where the electrified double track from the crusher enters the pit and spirals 3-1/2 miles to the bottom. A second approach at the east side enters the pit at a 2-percent grade and is used for waste haulage from the levels above 1660. Single tracks from benches are connected with the main line by switch assemblies which are called crossovers (fig. 48).

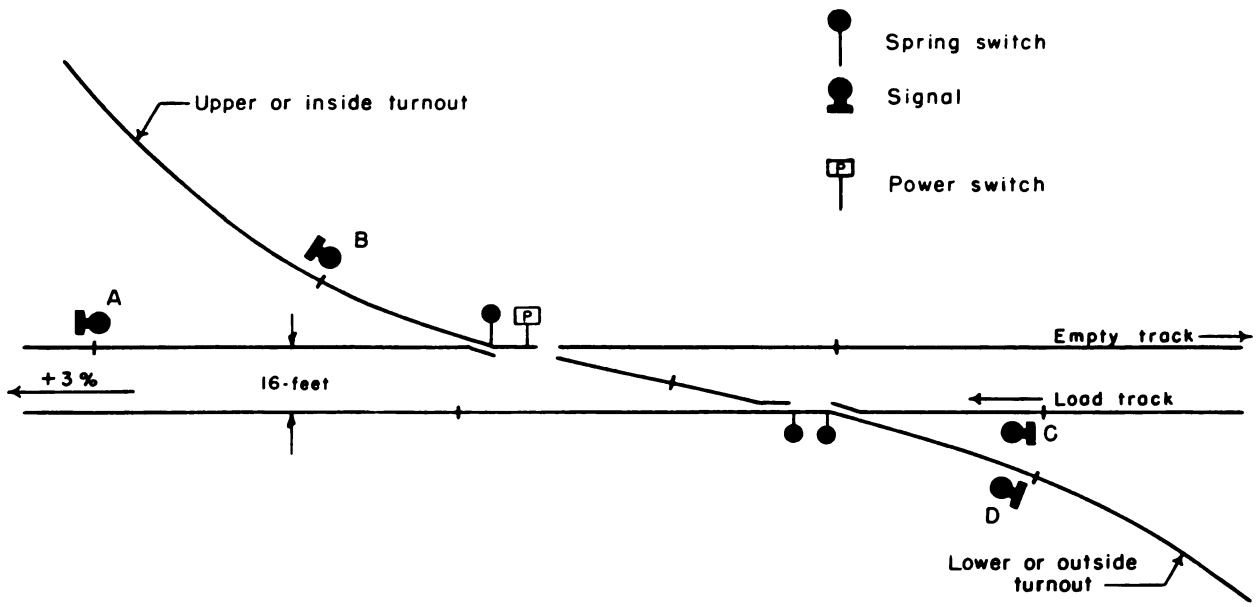

FIGURE 48. - Typical Crossover Layout, New Cornelia Mine.

These are numbered, starting below the crusher and extending to the bottom of the main-line track. Each crossover is equipped with signal lights. One power-actuated switch is placed at the upper end of the crossover on the return track. All others are spring switches lined for normal train movement.

18/ Barr, Alfred, T., Diesel Engines for Auxiliary Power on Electric Locomotives at Ajo: Paper delivered at Am. Min. Cong. Conv., Spokane, Wash., Sept. 27, 1949, 6 pp.

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Left-hand traffic is used and is controlled by a dispatcher in a lookout station from which he can observe the mine traffic. Power switches and signal lights are operated by a unit-wire system from a control board similar to that of a central traffic-control system. The system places all train movements in the hands of the dispatcher who can hold a train on the main line or a siding, instruct it to proceed after having been held, and line up its route.19/

The construction and maintenance of main-line haulage track, dismantling, and relocation of bench track, repair of yard track, and realinement of waste dump track are one of the largest elements of mining cost. On January 1, 1957, the track at the New Cornelia mine was divided as follows:

	Miles
Main line	17.3
Bench or loading	13.6
Yard	6.3
Dump	4.3
Total	41.4

Track crews are under a foreman who reports to the general mine foreman. A daily report is submitted (fig. 49) that details the accomplishments each day, and this information is posted to a monthly report.

A train crew consists of a locomotive engineer and a brakeman. The engineer is in charge, and he takes orders from the shift foreman as to loading and haulage and from the traveling engineer as to care and mechanical operation of the train. At the end of each shift the locomotive engineer submits a report, "Locomotive Engineer's Operating Report," that details the day's operation. He also submits special reports on all derailments and bad-order cars. A "Locomotive Engineer's Inspection Report" is made daily, checked by the traveling engineer, to show the mechanical condition of the locomotive.

Locomotive Data

Three types of locomotives are now in use at Ajo. They are 1,000- to 1,200-hp. diesel-electric, 1,750-hp. diesel-electric, and 1,800-hp. trolley electric, with two auxiliary 325-hp. diesel-electric units.

Locomotive haulage data are shown for 1956 in table 4. In comparing the figures for the small and large diesel-electric locomotives, it should be remembered that the small locomotive is used largely at the south end of the mine on the 2-percent grade, while the larger locomotive is used for the lower levels of the mine and hauls over the 3-percent grade.

The 1,000-hp. diesel-electric locomotives are 125-ton switcher type. Direct current is supplied to four traction motors by a generator driven by a 1,000-hp. diesel engine. The locomotive is mounted on two articulated

19/ Seaberg, E. T., Use of Signals and Power Switches in the Rail Haulage System at Ajo: Paper delivered at AIME Open Pit Division, Arizona Sec., Tucson, Ariz., Dec. 7, 1953, 10 pp.

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PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH — MINING DIVISION

DATE..... TRACK REPORT **FOREMAN** .....

PLACE OF WORK	BANK TRACK					SECTIONS				SWITCHES						LABOR		REMARKS
	Shftd	Built	Bkd	Out	Ballast	In	Built	Bkd	Out	Shftd	In	Built	Bkd	Out	Ballast	Men	Hours	
PIT — Level Shovel																		
DUMPS—Number																		
MAIN LINE																		

SUPPLIES USED	WHERE USED					MAINTENANCE—GEN.			
						REPAIR—WRECKS, BLASTS			
						POWER CABLE			
						PIT CLEAN-UP			
						MISC. SURFACE			
						HOIST			
						WELDER			

NOTE: REPORT TRACK WORK IN RAIL LENGTHS

FIGURE 49. - Track Report.

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trucks. Axles are spaced at 8 feet on the trucks; the trucks are spaced 22 feet center to center, and the overall length between coupler pulling faces is 44 feet 5 inches. Three of these locomotives were in use at Ajo when the mine was visited in December 1956. They were used principally to haul waste up the 2-percent grade at the south end of the pit and for general switching service.

TABLE 4. - Locomotive haulage data

Locomotive type	Electric with diesel auxiliaries	1,750-hp. diesel-electric	1,000- to 1,200-hp. diesel-electric
No. of units	8	7	3
Hp. trolley	1,800	-	-
Hp. diesel	650	1,750	1,000 - 1,200
Weight, tons	125	125	125
Tons hauled per shift	1,793	1,828	1,683
Ton-miles per shift	5,681	5,409	3,084
Gross work done per shift (thousand foot-tons)	1,483	1,320	705
Gal. fuel oil per shift	42.8	136.3	86.4
No. of cars per train	7	7	6

Until 1945 all main-haulage track was on 2-percent grade or less. About that time the decision was made to abandon steam haulage and use a 3-percent main-line approach. Main-line tracks were electrified, but loading tracks were not.

A type 0-4-4-0 trolley-type electric locomotive with two auxiliary 235-hp. diesel generators was purchased. This unit weighs 125 tons and is driven by four traction motors that produce a total tractive effort of 35,400 pounds. The machine is mounted on rigid trucks with axles spaced 9 feet 6 inches in a truck and trucks spaced 29 feet 7-1/2 inches, center to center. The length between coupler faces is 47 feet 4 inches. Power is collected from the trolley by a pantograph on main-line track or supplied by the two auxiliary diesel-electric generators when the locomotive is on loading tracks.

Trolley is supported by fabricated structure on permanent mainline (fig. 50) or by poles in the lower part of the pit where an occasional track move is necessary.

In 1955 and 1956 a 1,750-hp. diesel-electric locomotive was available. The truck design of this locomotive limits it to a maximum curve of 39°, but it is capable of rapid acceleration and handles seven-car trains easily on the 3-percent grade. At the end of 1956 there were seven of these locomotives in use at Ajo.

All locomotives are inspected and serviced once each shift. The complete train is removed from service and placed on one of the yard tracks near the crusher, carefully inspected for defects, then returned to service

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if no serious defects are found. A locomotive shop and car-repair yard are located near the crushers (fig. 51). Light repairs are made here; but, when serious defects are found or extensive overhaul is required, locomotives are removed from service and sent to the locomotive section of the main machine shop near the powerhouse. The repairs then are made by the maintenance division.

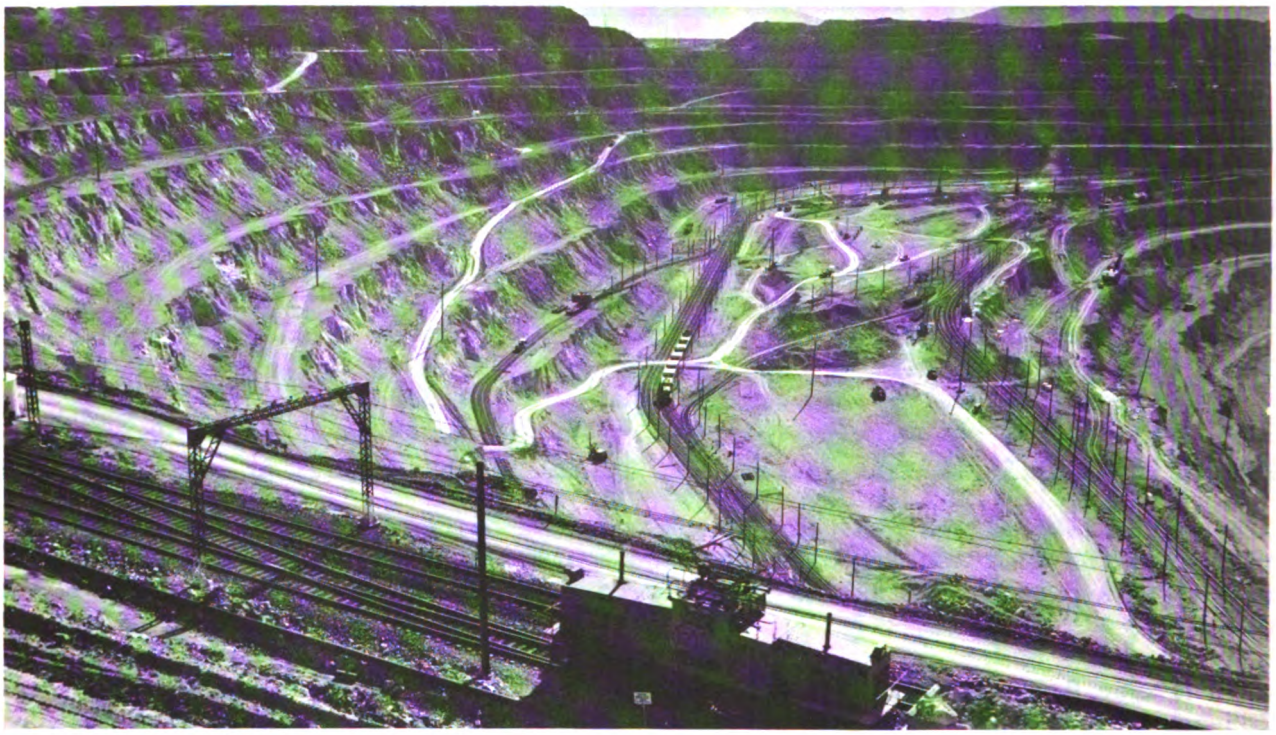

FIGURE 50. - Typical Main-Line Track.

Trolley Power

Power is generated by a steam-turbine-driven plant in the shop area, which utilizes waste heat from the smelter. The normal rate of evaporation is 50,000 pounds of water per hour in each of two boilers, representing a recovery of approximately 53 percent of the heat in the reverberatory fuel. The boilers in the powerplant are equipped to burn natural gas or fuel oil if required. Alternating current is generated at 13,600 volts and transmitted to a substation at a point near the junction of the waste-dump track with the main line from the pit to the crusher. Here the voltage is reduced in transformers and converted by rectifiers to 1,500 volts.

For 1956 power consumption was 0.80 kw.-hr. per ton of material hauled by the electric locomotives. These locomotives also consumed 0.024 gallon of diesel oil per ton of material in the auxiliary power units while the locomotives were operated on loading tracks. The diesel-electric locomotives consumed 0.070 gallon per ton of material hauled during the same period.

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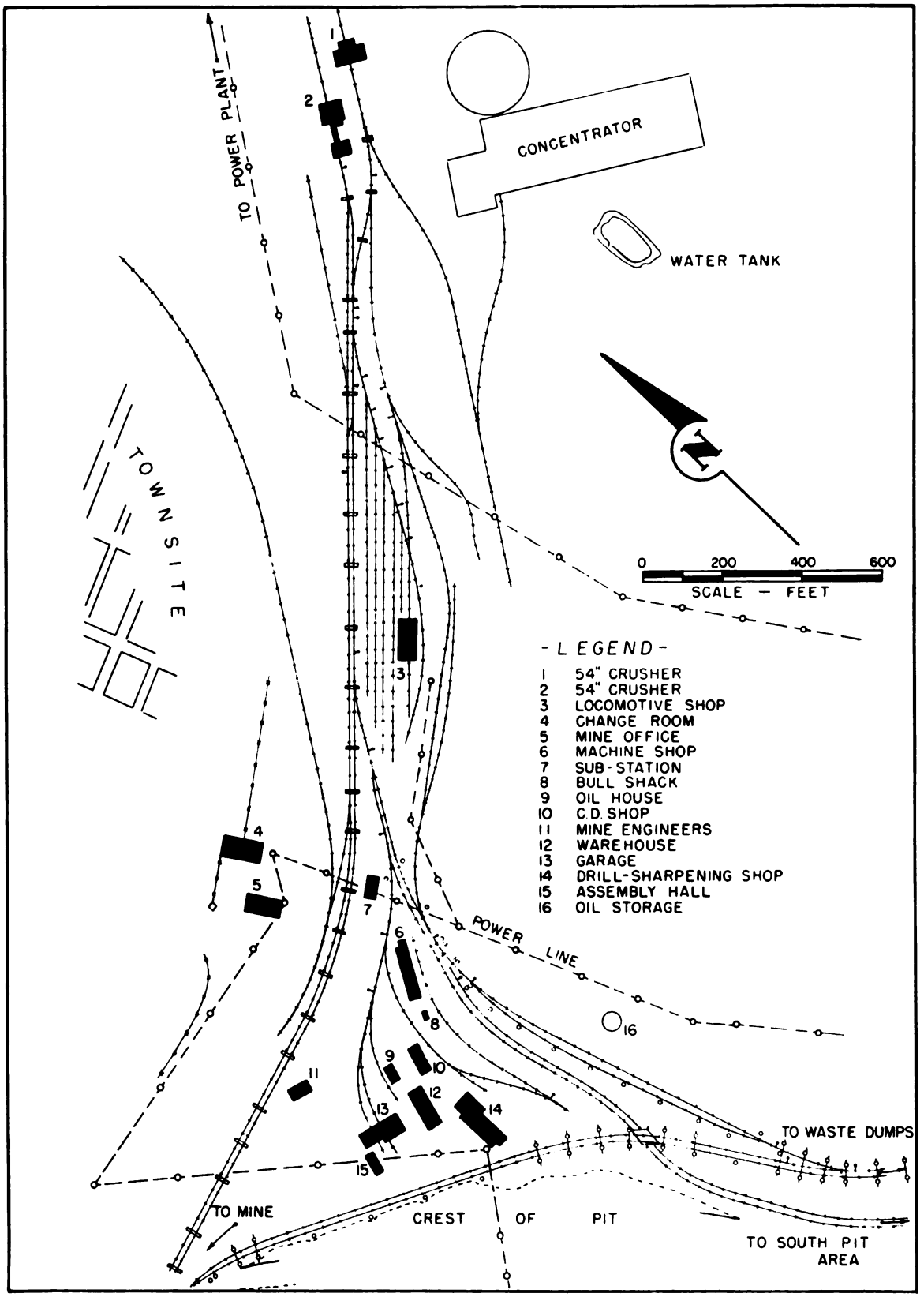

FIGURE 51. - General Layout of Mine Buildings.

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Ore and Waste Cars

Three types of cars are used, as follows:

(1) 30-yard capacity, empty weight 32 tons, mounted on trucks with solid axles and friction bearings.

(2) 30-yard capacity, empty weight 32.5 tons, mounted on trucks with solid axles and roller bearings.

(3) 20-yard capacity, empty weight 30 tons, mounted on solid-axle trucks with friction bearings.

Thirty-yard cars hauling about 60 tons each are used to transport ore and waste in seven-car trains. Twenty-yard cars are used to haul leach-plant tailings to the mine for use as blasthole stemming. All cars dump to either side by means of air cylinders, and the 30-yard cars are self-righting after the load has been dumped. All cars are equipped with airbrakes, and air is supplied by compressors on the locomotive, which maintain a brake-line pressure of 90 pounds and a main-reservoir pressure of 130 pounds. The cars have both train-line and dump-line air pipe, with standard airbrake hose couplings between cars. The caboose car on each train has an end sill 1 foot wide, with a metal sheet fastened to the top of the car and curved backward to form a canopy that protects the brakeman in case of a broken trolley wire.

Main-Line Track

Main-line tracks are used for the ore haul from mine to crusher and for waste haul to the dump area. Double tracks are spaced 16 feet center to center and are laid with 115-pound bonded rail. Fabricated-steel structures (figs. 50 and 52) are used to support the trolley wire where the alinement is permanent. On the lower part of the spiral, where an occasional move is necessary, wooden poles are used. A churn drill is used to make holes for the poles.

When a main-line track move is necessary, the new track is built in advance, and the connection is made when traffic will not be interrupted. All main-line track is ballasted (fig. 53). Ballast is spread by placing a crosstie in front of the rear truck of a hopper-type car, opening the gates, and pushing the car slowly forward.

Slag from the smelter is used for ballast. The slag is not crushed, but a special dump has been devised where the slag spreads in a thin sheet as it it poured. This slag cools rapidly and breaks into fine particles which are scraped into a pile by a dozer, loaded into a car by a dragline, and hauled to the mine.

Bench Tracks

A storage yard on one of the old dump areas is maintained to store track supplies and to make sections (fig. 54). Ties are spread out, and sections of track, one rail in length, are fabricated. When it is necessary to move

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the loading track closer to the bank, a bulldozer roughs in the grade, and a grader finishes the final subgrade (fig. 55). The sections of track from the old alinement or new sections from the storage yard are moved by a crane and placed in front as it advances (fig. 56). As sections are placed, the holes for fishplates are matched, and bolts are set to hold the rails in place. Finally, a track crew follows the panel crew and spikes the ties at rail joints, levels and blocks the track, replaces broken ties, and cleans up (fig. 57).

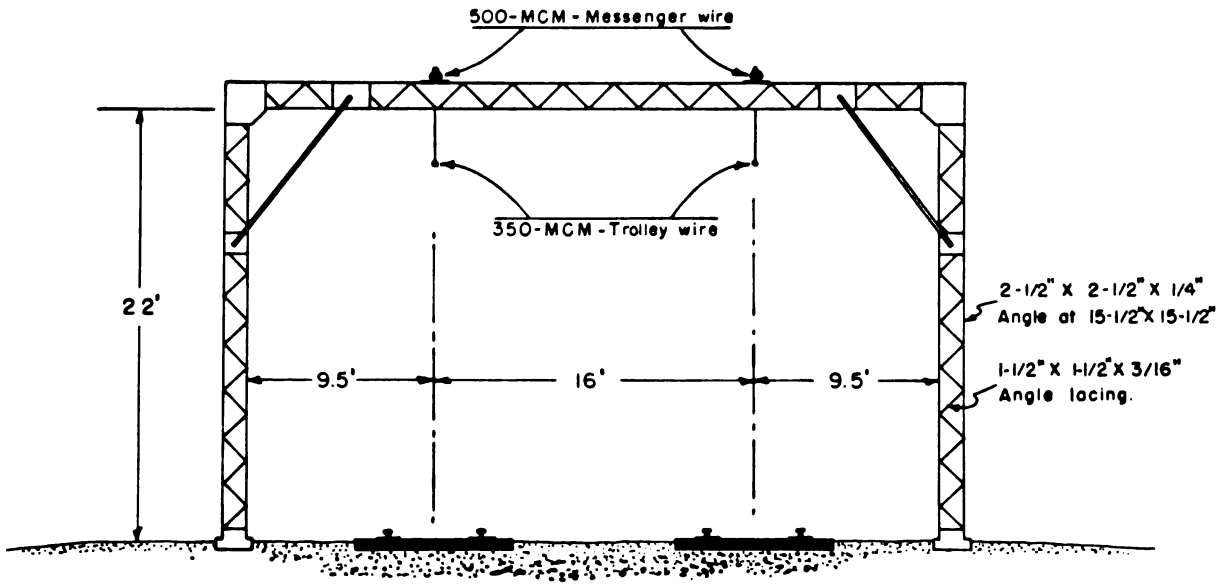

FIGURE 52. - Typical Trolley-Wire Support, New Cornelia Mine.

Switches are built in the track yard, stored until needed, then moved and set in place with a 50-ton crane.

Dump Track

The dump track is laid with 90-pound rail along the crest. Waste is dumped along the track until the cars can no longer be dumped, then the dump is said to be "plugged" (fig. 58). As a "plow" is pushed along the dump by a locomotive, the wings of the plow push the material over the crest, smoothing the area outside the track. The track then is moved out near the new crest with a trackshifter (fig. 59), and the cycle is repeated. The trackshifter is a standard unit manufactured by one of the regular suppliers of track machinery.

Yard Track

In the yards track is made with sections using 90-pound rail. Yard track is not subject to heavy traffic and requires attention only when damaged by accident. It is not bonded except in locations where it is subject to traffic by electric locomotives.

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FIGURE 53. - Typical Track Ballast and Trolley-Support Poles.

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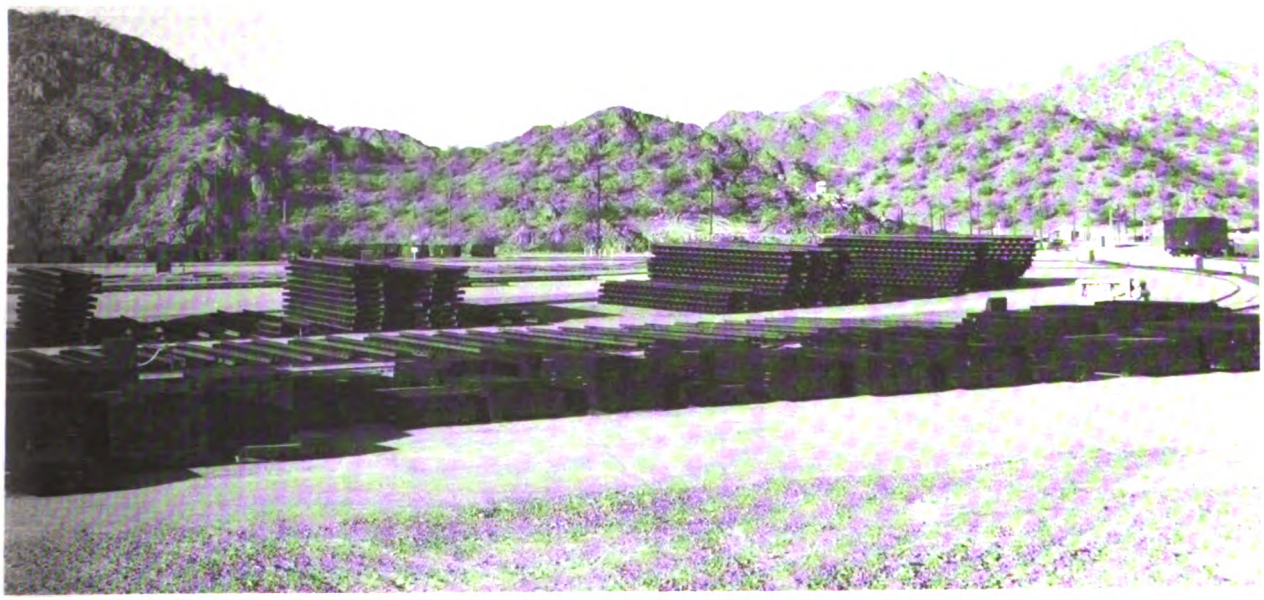

FIGURE 54. - Track-Supply Storage Yard.

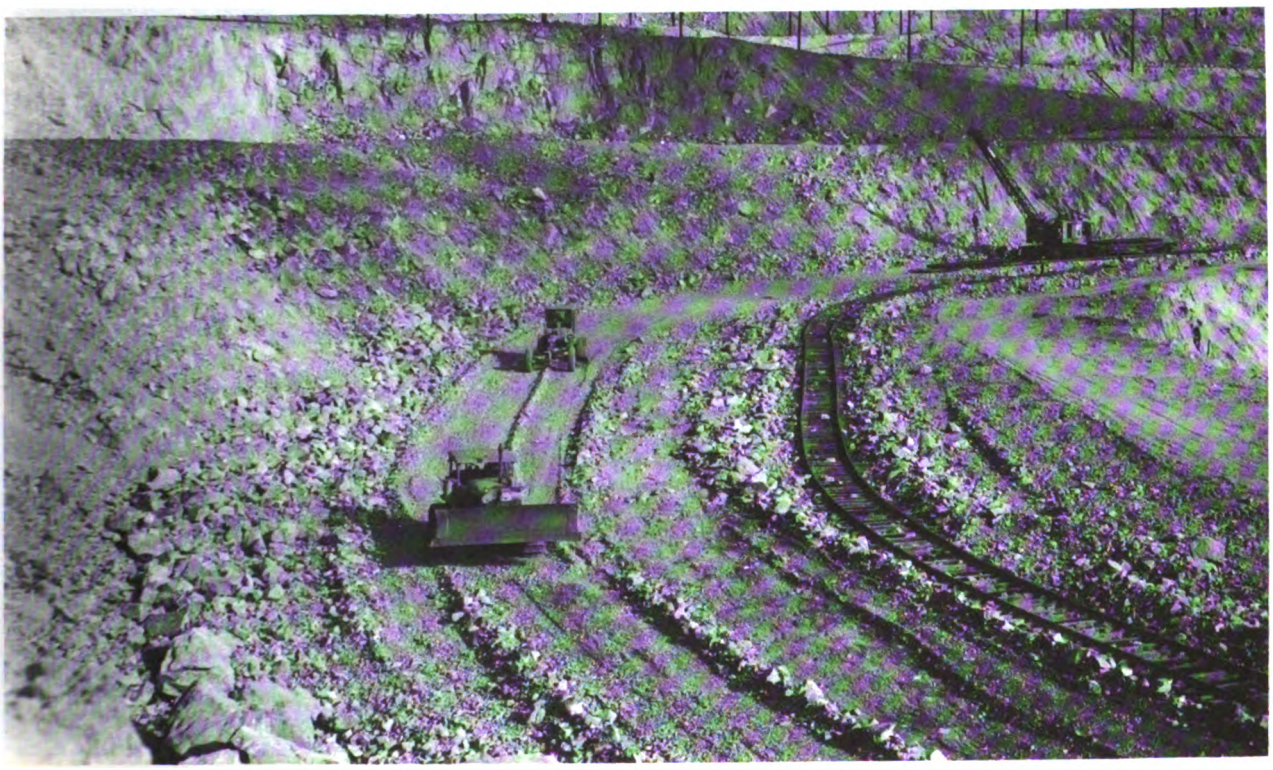

FIGURE 55. - Dozer and Grader Preparing Grade for Bench-Track Move.

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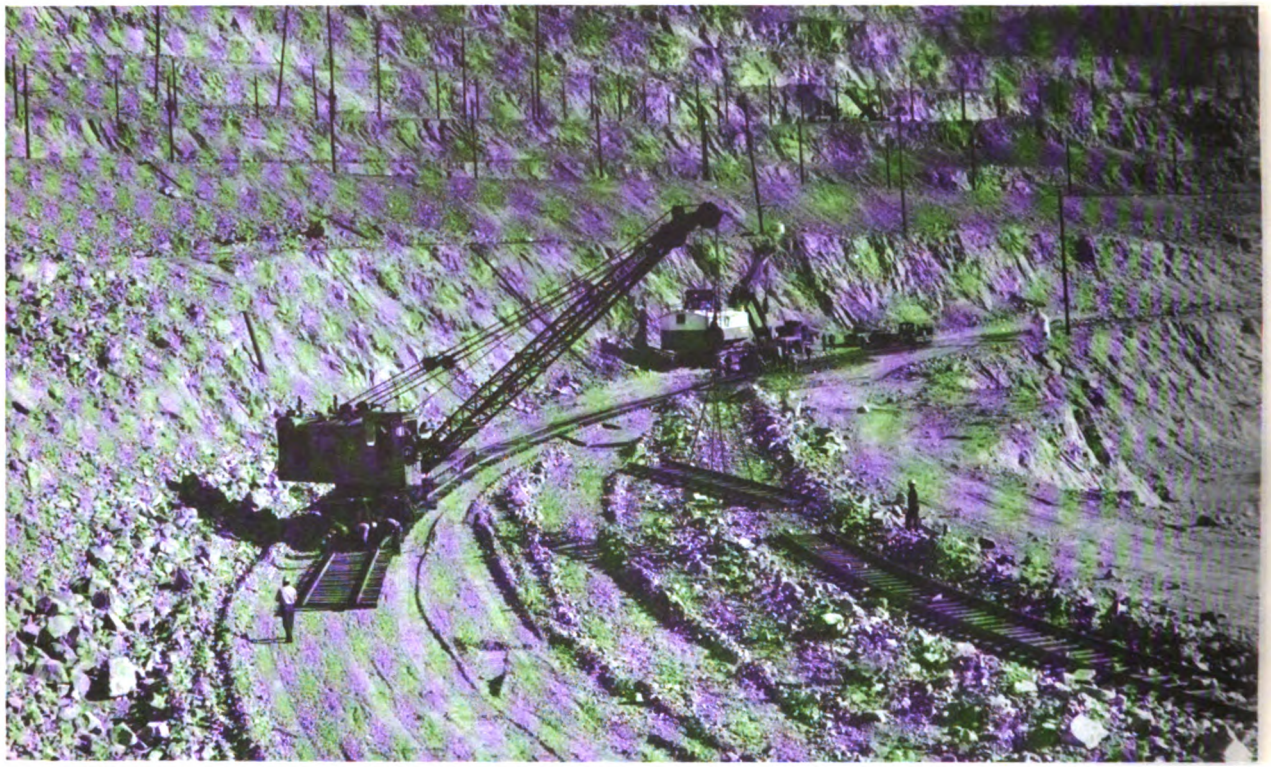

FIGURE 56. - Track Sections Are Moved to Place With Crane.

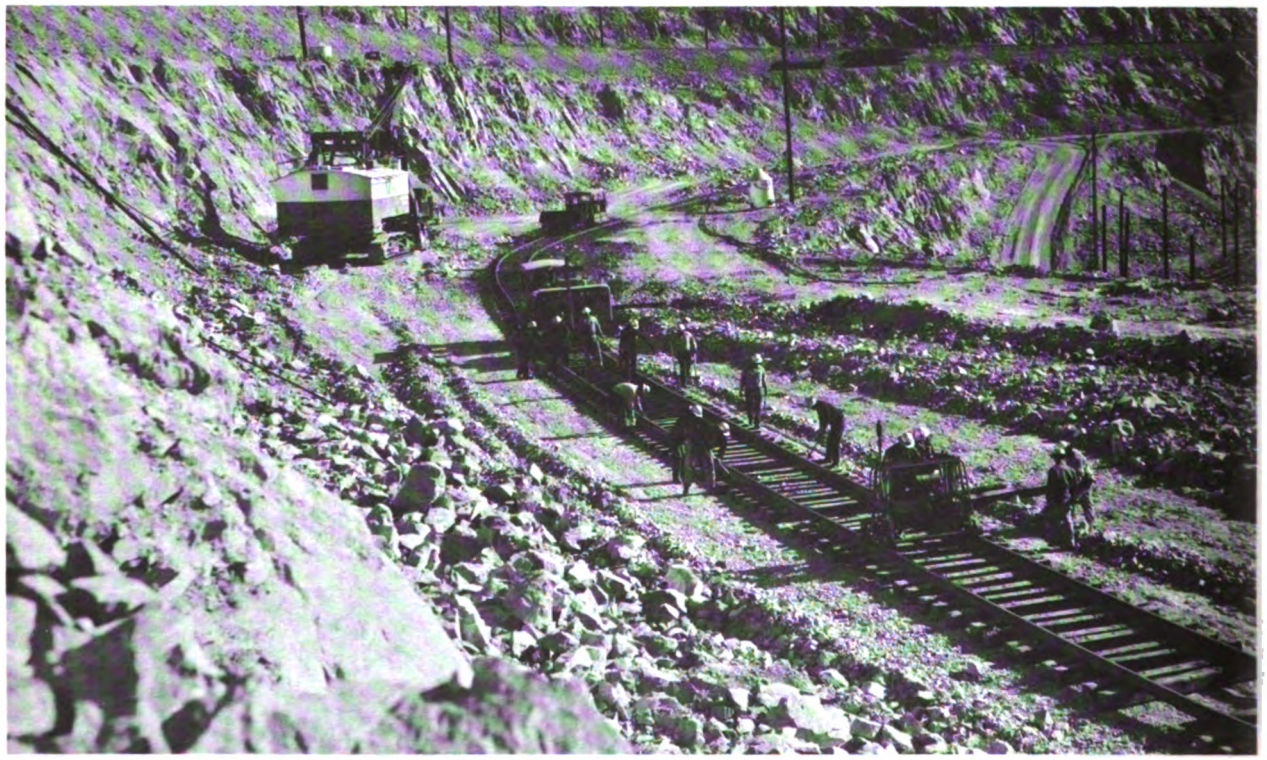

FIGURE 57. - Final Cleanup by Track Crew.

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FIGURE 58. - Dump Track "Plugged" at Near End.

FIGURE 59. - Trackshifter Moving Dump Track.

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Truck Haulage

The New Cornelia mine was one of the first open-pit copper mines to use off-highway-type trucks for haulage. In 1937 it became necessary to move a portion of a steep hill that extended about 500 feet above the average rim of the pit and covered an area roughly 2,000 feet in diameter at its base. The average haul for trucks was approximately 0.5 mile and was almost level.20/ Truck haulage was successful on this job, so it was used later on the west side of the pit to push the 1760 and 1820 levels back to pit limit and on the north side of the pit on the 1790 level to prepare for the new 3-percent main-line approach.

A fleet of eight 25-ton-capacity dump trucks was in use at Ajo when the mine was visited.

Truck haulage at New Cornelia has been successful for special operations. Although not used continuously, trucks are available and are used for the following purposes:

1. To move waste above train haulage levels where initial construction of a track is costly or impractical.

2. To prepare the initial grade for a new waste-dump track.

3. To open initial grade down to a new level in the mine.

4. To make fills in the townsite or plant area, and on general construction projects.

A repair garage is provided for truck service. This garage also provides service for more than 100 pieces of rubber-tired equipment, such as pickup trucks, motor graders, rubber-tired dozers, and other units that are used in routine mine operation. More than 30 miles of road is maintained in the mine area.

Engineering Control

Engineering control is used for the following purposes at the New Cornelia mine:

1. To maintain records and maps that will give a clear picture of past operations and also provide a basis for current and future operations.

2. To prepare plans for monthly, yearly, and longer range mining operations.

3. To control the grade of ore mined and to determine and designate material to be wasted.

20/ Angst, Harry A., Trucking Operations at New Cornelia Mine: Trans. AIME, Vol. 153, 1943, p. 137.

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4. To supervise sampling of blastholes drilled in ore and to supervise development drilling.

5. To determine drilling depth of blastholes, calculate burden on holes, and survey blastholes so that locations can be plotted on map.

Blastholes are sampled as they are drilled, and the sample is processed before delivery to the laboratory, as shown by the flowsheet in figure 60.

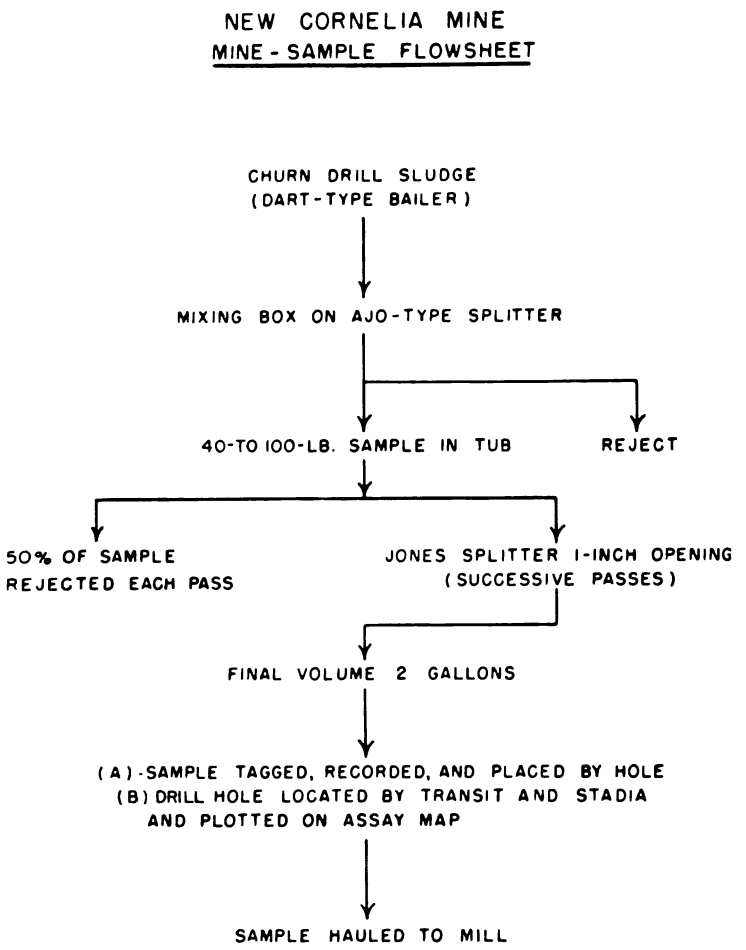
NEW CORNELIA MINE
MINE - SAMPLE FLOWSHEET
CHURN DRILL SLUDGE
(DART-TYPE BAILER)
MIXING BOX ON AJO-TYPE SPLITTER
40-TO 100-LB. SAMPLE IN TUB
REJECT
50% OF SAMPLE
REJECTED EACH PASS
JONES SPLITTER 1-INCH OPENING
(SUCCESSIVE PASSES)
FINAL VOLUME 2 GALLONS
(A) - SAMPLE TAGGED, RECORDED, AND PLACED BY HOLE
(B) DRILL HOLE LOCATED BY TRANSIT AND STADIA
AND PLOTTED ON ASSAY MAP
SAMPLE HAULED TO MILL

FIGURE 60. - Mine-Sample Flowsheet.

The hole is located, and the faced-up bank is surveyed by stadia, then plotted on a map. As loading track is placed in position, it is stationed from the main-line switch on each level, and the station points are located on the mine map (fig. 61). The drill holes are represented by a circle on the map, and the assay is written in this circle to the nearest 0.1 percent. The assay also is recorded in an assay book by level and series to the nearest 0.01 percent (fig. 61).

The ore-control engineer or the mine foreman can spot the position of a shovel accurately at any time by noting the position and the station point along the loading track. By noting the sample holes along the bank from the present position to the last position on the mine map and referring to the assay book, the grade of ore mined during any given interval is determined. By combining tonnage and grade for all shovels, the engineer can compute the grade of the total tonnage from the mine for the period.

The ore is sampled at the mill with an automatic sampler. Over a period of a month the grade estimated by the ore-control engineer and that resulting from the automatic sampler do not differ by more than 0.02 or 0.03 percent copper.

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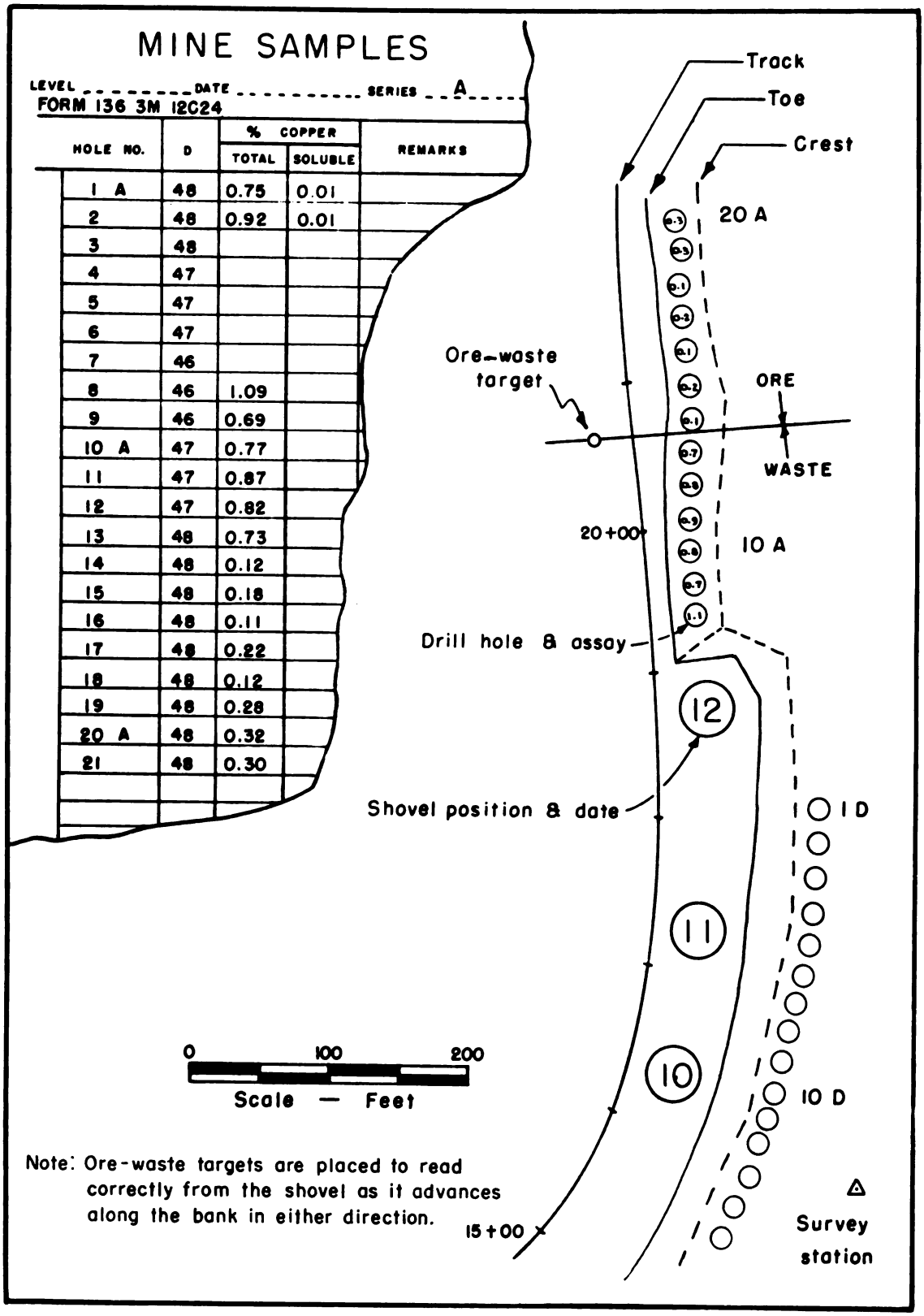

FIGURE 61. - Hypothetical Bank Map.

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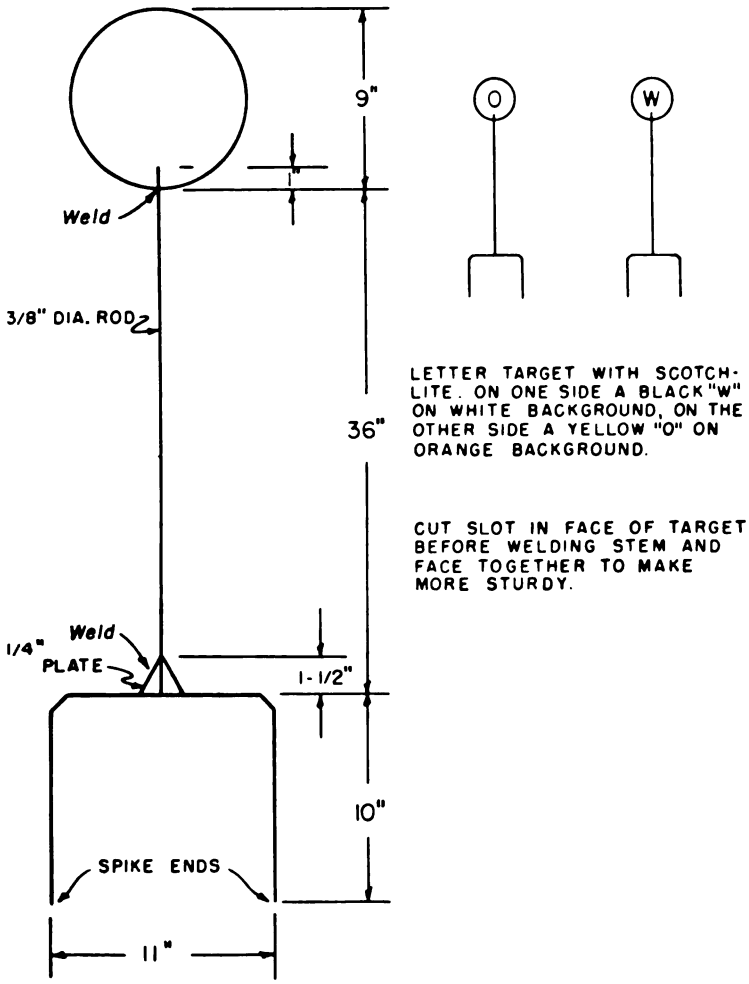

FIGURE 62. - Ore-Control Target, New Cornelia Branch.

The grade of ore is quite uniform by areas. When waste areas are encountered the ore-control engineer places an ore-waste target (fig. 62) along the track (fig. 61). This enables the foreman and shovel operator to see exactly where the shovel should change from ore to waste or waste to ore.

As the sample holes are located by the survey party, the interval between the holes, the elevation of the top of the hole, and the distance from hole to crest are measured. The distance from hole to toe, the theoretical loading depth, and the total burden in cubic yards are computed; all this information is given to the drilling and blasting foreman on the powder-loading sheet.

As the loading track is surveyed, the elevation of each 100-foot point is determined. When it is obvious that the digging grade of the shovel is not correct, stakes marked to cut or fill as required are placed along the track to guide the foreman and shovel operator.

Each morning the ore-control engineer visits each shovel, records the exact location, and examines the material in front of the shovel. Returning to the office, he computes the grade of the ore mined by each shovel and submits a report to the engineering office with a copy to the general mine office (fig. 63).

Operating Control

At the New Cornelia mine operating control is accomplished by verbal or written orders from the mine superintendent through the general mine foreman and the various subforemen. Production results are recorded by a system of reports that are consolidated in daily (fig. 64), monthly, and annual reports of the mine superintendent to the manager.

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PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH

ENGINEERING DEPARTMENT

DAILY MINE REPORT

Ajo, Arizona

Shovel No.	Location at End of Day	ORE				WASTE			
		TODAY		MONTH		TODAY		MONTH	
		Tons	% Cu.	Tons	% Cu.	Tons	% Cu.	Tons	% Cu.

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH — MINING DIVISION
AJO, ARIZONA

DAILY MINING REPORT

Date .....

Shovel Number	Level	Tons Produced Today			Shovel No.	Tons Produced This Month to Date			Total Tons Last Month
		Ore	Waste	Total		Ore	Waste	Total	
14					14				
26					26				
Tks.					Tks.				
Total					Total				
A Shift									
B Shift					Av/Day				
C Shift									

Shovel Number	Shifts Worked	Tons Per Shovel Shift — Today			Shifts Worked	Tons Per Shovel Shift—Month to Date			Tons Per Shovel Shift Last Month
		Ore	Waste	Total		Ore	Waste	Total	
14									
15									
26									
Tks.									
Total									
A Shift									
B Shift									
C Shift									

GENERAL OPERATING STATISTICS	Totals		Averages Per Day	
	Today	Month To Date	This Month	Last Month
Number of Days Operated				
Number of Man-Shifts Worked				
Number of Men Off				
Tons Mined per Man-Shift — Total Material				
Waste Ratio				
Tons of Ore Milled — Dry Tons				
Grade of Ore Milled — % Cu.				
Total Locomotive Shifts				
Locomotive Shifts — Switching				
Locomotive Shifts — Haulage				
Car Factor — Tons per Car				
Tons per Locomotive Haulage Shift				
Trains Delayed Waiting for Shovels — %				
Shovels Delayed Waiting for Trains — %				
Total Truck Shifts				
Truck Factor — Tons per Truck				
Tons per Truck Shift				
Trucks Delayed Waiting for Shovels — %				
Shovels Delayed Waiting for Trucks — %				

Remarks:

.....
Mine Superintendent

FIGURE 64. - Mining Division, Daily Mine Report.

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A clerical and accounting section, reporting directly to the mine superintendent, collects the various production reports and consolidates them in order to organize information for the daily mine report. All employees check in and out of a time office in the mine office and then are hauled in buses to their working places. Foremen are equipped with a pickup truck and radio and assist in transporting men to their working places.

A two-way radio system, first used in 1950, has made possible better coordination of supervisory effort.21/ The New Cornelia pit is favorably situated for shortwave transmission, because distances are short, and topography does not interfere. One frequency (154.52 Mc) is used exclusively for rail haulage, and another (154.49 Mc) for foremen's trucks and supply units. Two fixed stations, one at the mine office and one at the "Lookout" on the edge of the pit, have a 30-watt power supply; the mobile stations, those in pickup trucks, and locomotives, have a 10-watt power supply.

PERCENTAGE OF EXTRACTION AND PRODUCTION RATE

Because all material is removed from the pit, the ore extraction is 100 percent. A very small percentage of the ore is diluted with waste and sent to the dumps. Some highly oxidized ore that is mined from the old erosional contact along the south side of the pit is sent to the dump. An extensive horst of very low-grade material existed in the levels above the 1200 in the sulfide zone. As it was necessary to mine this ore at a rate that (if it were all sent to the mill) would unduly lower the grade of the mill feed, it was placed on a separate dump, where it is available.

In the areas that have been mined to date, the overall recovery versus the expectancy from drill-hole estimates is as follows:

	Percent
Tonnage	104.1
Grade	99.1
Copper content	103.2

Operating at the rate of 31,503 tons of ore and 45,184 tons of waste per day the mine produced a maximum of about 4 tons of ore per linear foot of developed 40-foot bank.

MINE DRAINAGE

Most parts of the mine area drain well. Almost all of the sulfide ore is below permanent water level, and a deep-well type pump placed in a drill hole keeps the water below the lowest operating level. A mine flow of approximately 200,000 gallons per day is pumped to the concentrator and used for processing.

21/ Lentz, John A., Jr., Radio Communications in the New Cornelia Pit: Min. Cong. Jour., vol. 42, No. 5, May 1956, p. 42.

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FIRE PREVENTION

Fire protection is provided by a system of fire hydrants placed in accordance with the recommendations of the Fire Underwriters National Board. Plant and mine buildings, principal buildings in town, and residences are protected in this manner. The company provides equipment, and a volunteer fire department is organized and maintained at company expense. Fire extinguishers are placed in convenient places on equipment. Sections in the New Cornelia Branch General Safety Rules provide general fire prevention information and instructions.

SAFETY AND FIRST-AID TRAINING AND ORGANIZATION

The safety work at the New Cornelia Branch is organized as a department under the Administrative Division. It is directed by a safety supervisor who reports directly to the manager.

The Safety Department coordinates the accident-prevention and safety educational program. Its functions are primarily planning and advisory, and the operating supervisors are responsible for putting into practice approved safety methods.

The attitude of the management toward safety can best be described by quoting the following introductory sentences from the foreword in the "General Safety Rules for the Branch" given to each employee:

> The company sincerely believes that no job is done properly unless it is done in the safest possible manner. It is not enough, however, that only the managerial and supervisory forces be responsible for the safety of the employees. Experience has taught that only where every employee accepts his share of the responsibility for safety can accidents be reduced to a minimum.

The safety-policy-forming group is the Branch General Safety Committee, which consists of the heads of all the divisions at the branch. The branch manager is chairman, and meetings are held monthly. Each division has a committee that consists of all foremen in the division. Each department or unit is a committee that consists of all employees in that unit. These committees hold meetings once each month; minutes are taken, and anything of importance is referred to the division committee.

"Codes of Safe Practice" are developed for all operations. These codes are the result of cooperative effort by the safety engineer, foreman, and employees. Each employee is furnished with a code covering his line of work and while on the job is required to follow the procedures outlined. New employees or employees changing from one job to another attend instruction classes on the applicable code. Pertinent statistics on the status of codes are reported for each year in the Annual Safety Report. For 1956 these were as shown in table 5:

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TABLE 5. - Codes of safe practice - 1956

Codes completed	7
Codes revised	3
Codes in effective use	95
Code instruction class	63
Hours of code instruction	758
Men completing classes	1,520
Code reviews	62
Code review attendance	622
Change of occupation examinations	322
Branch codes completed and in effective use not included in above figures	14

Each "Code of Safe Practice" follows a general outline illustrated by the following table, which is the index from the code for churn drilling:

TABLE 6. - Code of safe practice for churn drilling (index)

I. References

- A. Code of Safe Practice for Churn Drilling, New Cornelia Branch, Phelps Dodge Corp.
- B. Code of Safe Practice for Churn Drilling, Morence Branch, Phelps Dodge Corp.
- C. Care, Maintenance, and Operation of Bucyrus Erie Drills, Bucyrus Erie Corp.

II. Description of Job

- A. Objective
- B. Hazards

III. Crews, Duties and Responsibilities

- A. Personnel
- B. Qualifications
- C. Training for the job
- D. Duties of crew members
- E. Apparel

IV. Equipment and Material

- A. Machinery
- B. Tools

V. Preparation and Housekeeping

- A. Illumination
- B. Housekeeping

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TABLE 6. - Code of safe practice for churn drilling (index) (Con.)

VI. Procedures and Precautions

- A. Inspection of equipment
- B. Lubrication and minor operating repairs
- C. General procedures and precautions
- D. Applying power to the drill
- E. Setting up and leveling the drill
- F. Starting the hole, setting collar casing
- G. Drilling the hole
- H. Bailing out the hole
- I. Blasthole sampling
- J. Changing bits
- K. Pulling the casing
- L. Moving the drill
- M. Fishing for lost tools
- N. Closing down the drill

VII. Coordination with other jobs

VIII. Procedure in Emergencies

- A. Electric storms
- B. Power failure
- C. Drill in contact with powerlines

IX. Procedure in case of injury

- A. Minor injury
- B. Major injury
- C. Accident not resulting in injury

A safety-suggestion system is in use under which employees are encouraged to make suggestions to improve the safety of their jobs. Each suggestion is investigated.

Regular unit or job inspections are made monthly.22/ A general pit inspection is made twice each year by a committee composed of both foremen and workmen. In making the inspection the committee is guided by inspection sheets that include lists of questions. All defects are listed on the follow-up form which is sent to the foreman concerned for corrective action.

All accidents are investigated by an "Initial Investigating Committee" composed of the foreman in charge of the operation in which the accident occurred and one workman. The committee assembles the facts and suggests remedial action. If the accident is serious or involves lost time, it is investigated a second time by a "Lost-Time Accident Investigating Committee".

22/ Wetzel, Victor O., Accident Prevention Program of the Mining Division, New Cornelia Branch, Phelps Dodge Corp.: AIME, Open-Pit Division, Arizona Sec., Tucson, Ariz., Dec. 10, 1951, 7 pp.

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The function of this group is to conduct a detailed and complete investigation. Specialized personnel or the help of other departments is obtained when needed. At the end of each month an "Accident-Classification Committee" reviews the current month's accident reports to determine the validity of the causes and the assignments of responsibility before the reports are referred to the division safety committee.

Monthly and annual reports summarizing all accidents are made, and significant trends in accident experience are used to direct future emphasis of the safety department. Table 7 listing statistics for 1956 indicates the scope of safety activities at the New Cornelia Branch.

The company provides certain items of properly approved personal protective equipment such as hard hats and safety glasses. These are issued to new employees and must be returned when they leave company service. The use of safety shoes is required on most jobs in the mine.

TABLE 7. - Safety activity report - 1956

			1956
Meetings			
Safety meeting held			618
Attendance			11,074
Possible attendance			11,768
Attendance		percent	94.1
Safety Suggestions			
Suggestions submitted			276
Status of suggestions:			
Completed	193	percent	69.93
Rejected	52	do	18.84
Pending	31	do	11.23
Total	276	do	100.00
Inspections			
Inspection made			634
Defects reported			2,251
Status of defects:			
Corrected	2,037	percent	90.49
Rejected	65	do	2.89
Pending	149	do	6.62
Total	2,251	do	100.00

Employees are insured under the Workman's Compensation Law of Arizona. Every employee who is injured must report to his foreman and to the company doctor as soon as possible. An employee instructed by the doctor to lay off work must have a release before returning to work. When he returns to the mine the employee must present the doctor's release to his foreman who initials the slip and returns it to the employee. The employee presents the initialed slip to the timekeeper and receives his card.

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TABLE 8. - Frequency and severity statistics for New Cornelia mine

	Open-pit mine, 1956	New Cornelia Branch, 1956	New Cornelia Branch, 1950-54	New Cornelia Branch, 1945-54
Exposure--work shifts...	184,752	473,500	2,203,221	3,841,927
Exposure--yearly average	184,752	473,500	440,644	384,193
Frequency--number of cases[1] (yearly average).....	4	9	24.1	20.3
Frequency per 1,000,000 man-hours.....	2.71	2.37	6.84	6.60
Severity--number of work shifts[2].....		114	49,152	64,713
Severity--percent of total work shifts exposure.....		0.024	2.231	1.684

1/ Includes fatal, serious, and slight injuries.
2/ Includes fatal, permanent total, permanent partial, and temporary injuries.

NOTE: The number of work shifts used as a measure of severity is taken from the scale of time losses for weighing industrial disabilities in order to show severity of accidents prepared by the International Association of Industrial Boards and Commissions.

WAGE SYSTEMS

The New Cornelia mine is operated on a straight wage and salary basis. Leasing, contracting, or bonus systems are not used.

ORGANIZATION

The Phelps Dodge Corp., with main offices at 300 Park Ave., New York, N. Y., is an integrated unit engaged in mining, concentrating, smelting, refining, fabricating, and selling copper and copper products. The company was incorporated in New York in 1885 as the Copper Queen Consolidated Mining Co. This name was changed to the present title in 1917. Mining operations are organized as branches under the general direction of a vice president and a general manager of western operations with offices at Douglas, Ariz.

The New Cornelia Branch was the largest copper producer in Arizona and the corporation's largest producer until it was superseded by the Morenci Branch. The branch is organized under a branch manager who reports directly to the general manager at Douglas.

The branch operating organization (fig. 65) is directed by the branch manager. The open-pit operating organization is given in figure 66.

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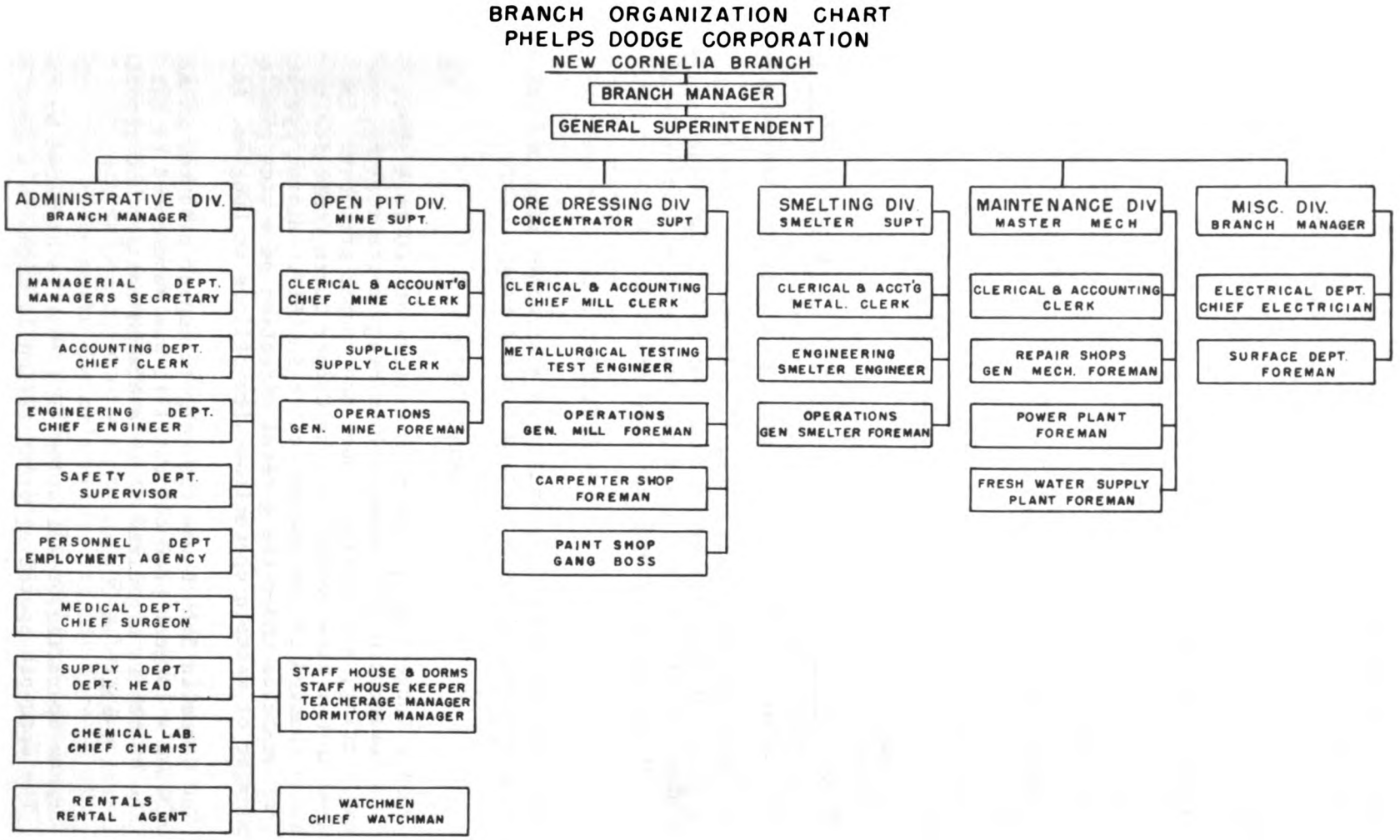

FIGURE 65. - Branch Organization Chart.

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PHELPS DODGE CORPORATION

NEW CORNELIA BRANCH

OPEN PIT DIVISION

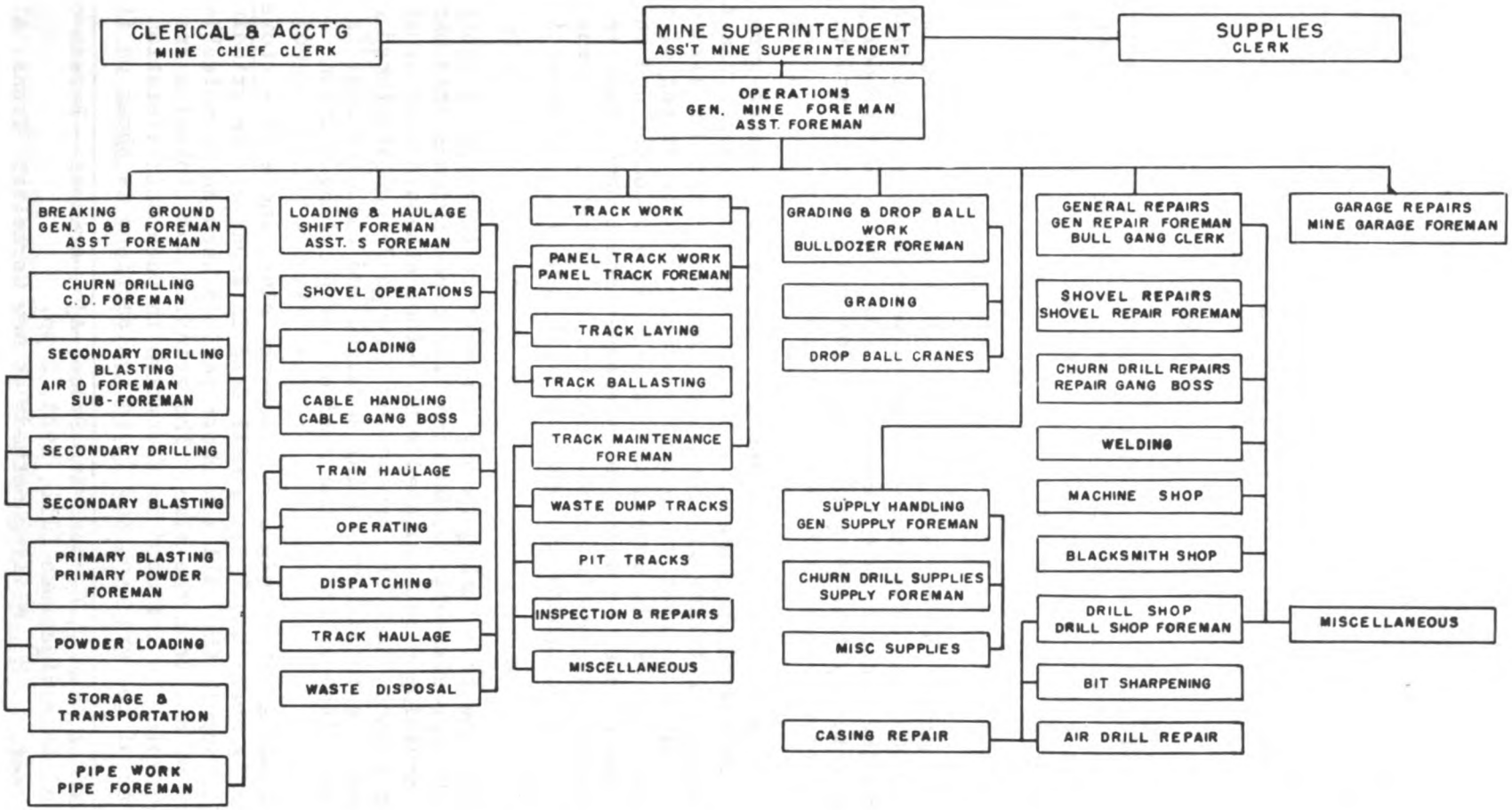

FIGURE 66. - Mine Organization Chart.

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AUXILIARY OPERATIONS

Operated as associated companies of the New Cornelia Branch of Phelps Dodge Corp. are the Tucson, Cornelia, and Gila Bend Railroad Co., the Ajo Improvement Co., and the New Cornelia Cooperative Mercantile Co.23/ These companies provide rail transportation, utilities, and shopping facilities for the employees. The mining company owns many of the buildings in the townsite; homes are rented to employees; and business places are leased to tenants.

PROCESSING PLANT

A detailed description of the processing plant is beyond the scope of this paper. However, the following brief description is helpful to properly evaluate some phases of mine design, particularly as it pertains to transportation and disposition of the ore.

Concentrator

The sulfide concentrator started operating in 1924 with a daily capacity of 5,000 tons. The number of units was increased from five to eight in 1929, and the capacity was raised to 16,000 tons. The capacity24/ has since been increased by improvement in crushing and grinding, and in 1956 the concentrator processed 31,503 tons per operating day.

Ore from the mine is delivered to one of two 54-inch gyratory crushers with a capacity of approximately 900 tons per hour each. Ore is delivered to both crushers in trains of 30-cu. yd. cars. The maximum size of ore from the mine is limited to that which will pass through the dipper of the shovel. At one crusher the ore is dumped into a 600-ton ore pocket and then fed to the bowl of the crusher by an 8-foot manganese-steel apron-type feeder. At the other crusher the ore is dumped from the car directly into the bowl of the crusher. Both crushers are operated with a 4- to 6-inch setting on the closed side.

Undersize from both gyratory crushers is conveyed to intermediate storage bins with approximately 20,000 tons live capacity, and then through an intermediate crushing plant equipped with 7-foot standard-cone crushers to a fine crushing plant. Here the ore passes through 7-foot shorthead cone crushers in closed circuit with vibrating screens, and the discharge is conveyed to a 16,000-ton fine-ore bin at the head of the grinding section.

Including intermediate and fine-ore bins, there is a storage capacity of slightly more than 1 day's mill feed in front of the grinding section. This will supply the mill for short periods when an unavoidable delay prevents delivery of ore from the mine. The grinding and flotation are simple; two-stage grinding is followed by flotation in pneumatic flotation machines. A flowsheet of the grinding and flotation sections is shown on figure 67.

23/ Gardner, E. D., Cooperative Store, Ajo, Arizona: Bureau of Mines Rept. of Investigations 2151, 1920, 2 pp.

24/ Barker, L. M., Milling Methods at New Cornelia: Trans. AIME, vol. 134, 1939, pp. 434-439.

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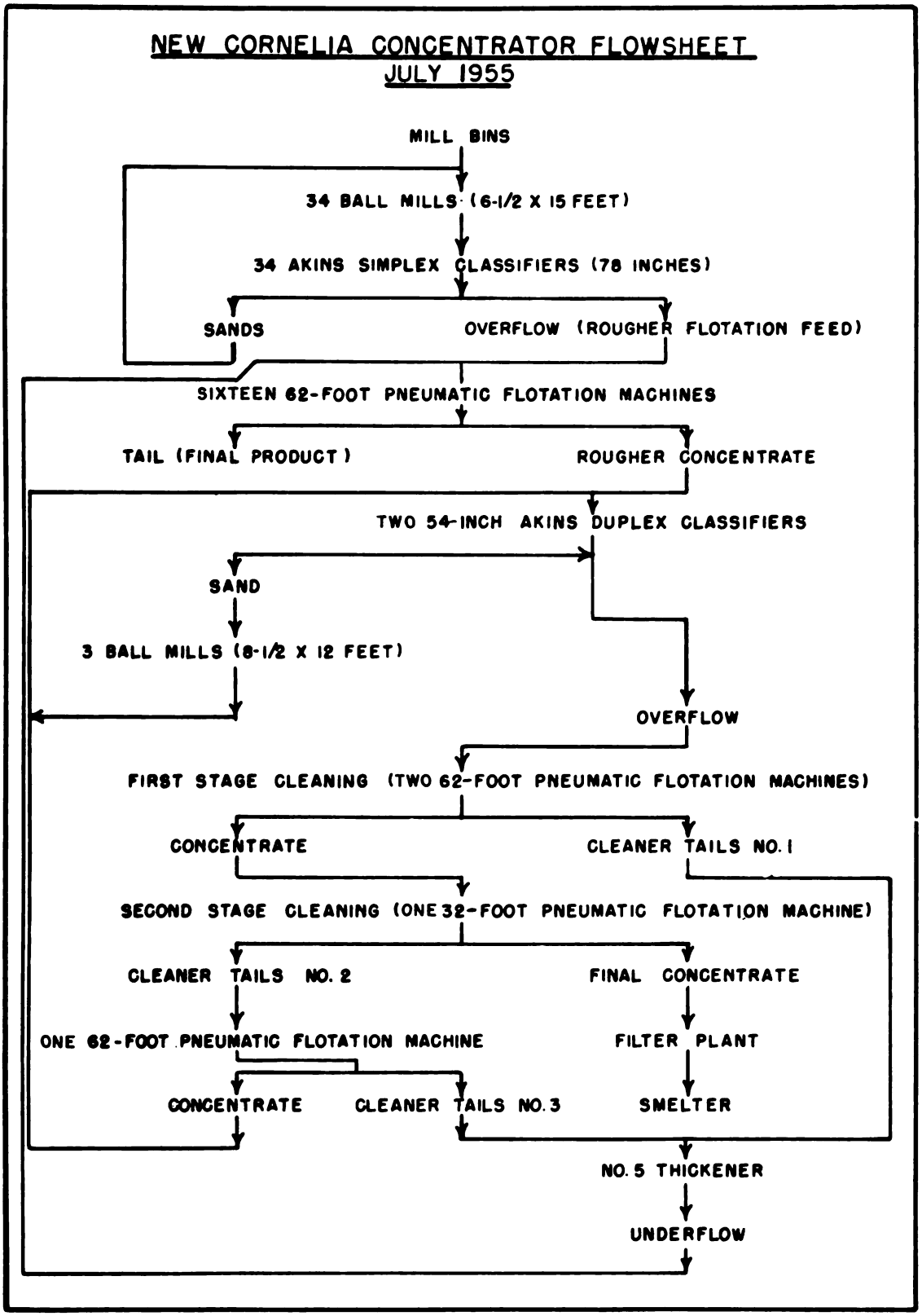

FIGURE 67. - Concentrator Flowsheet.

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Final flotation concentrates are filtered and conveyed directly to the smelter. Tailings are pumped to a pond where water is recovered, returned to the mill, and reused.

Smelter

Before 1950 New Cornelia ore was concentrated at Ajo, and the concentrates were sent by rail 300 miles to the Phelps Dodge smelter at Douglas, Ariz., for processing. In July 1950 a smelter was completed and "blown in" at Ajo.25/

The wet concentrate with a copper content ranging from 25 to 35 percent is mixed with lime flux and charged directly to the 30- by 100-foot reverberatory furnace. Matte is reduced in two 13- by 30-foot Peirce-Smith converters in charges of approximately 60 tons. The product, blister copper, is fed to the anode furnace and cast in 700-pound anodes for shipment to the refinery. A flowsheet of the smelter is shown in figure 68. Production amounts to about 200 tons of copper per operating day.

25/ Byrkit, J. W., Operations at New Cornelia Copper Smelter of Phelps Dodge Corp.: Trans. AIME, vol. 197, 1953, pp. 633-642.

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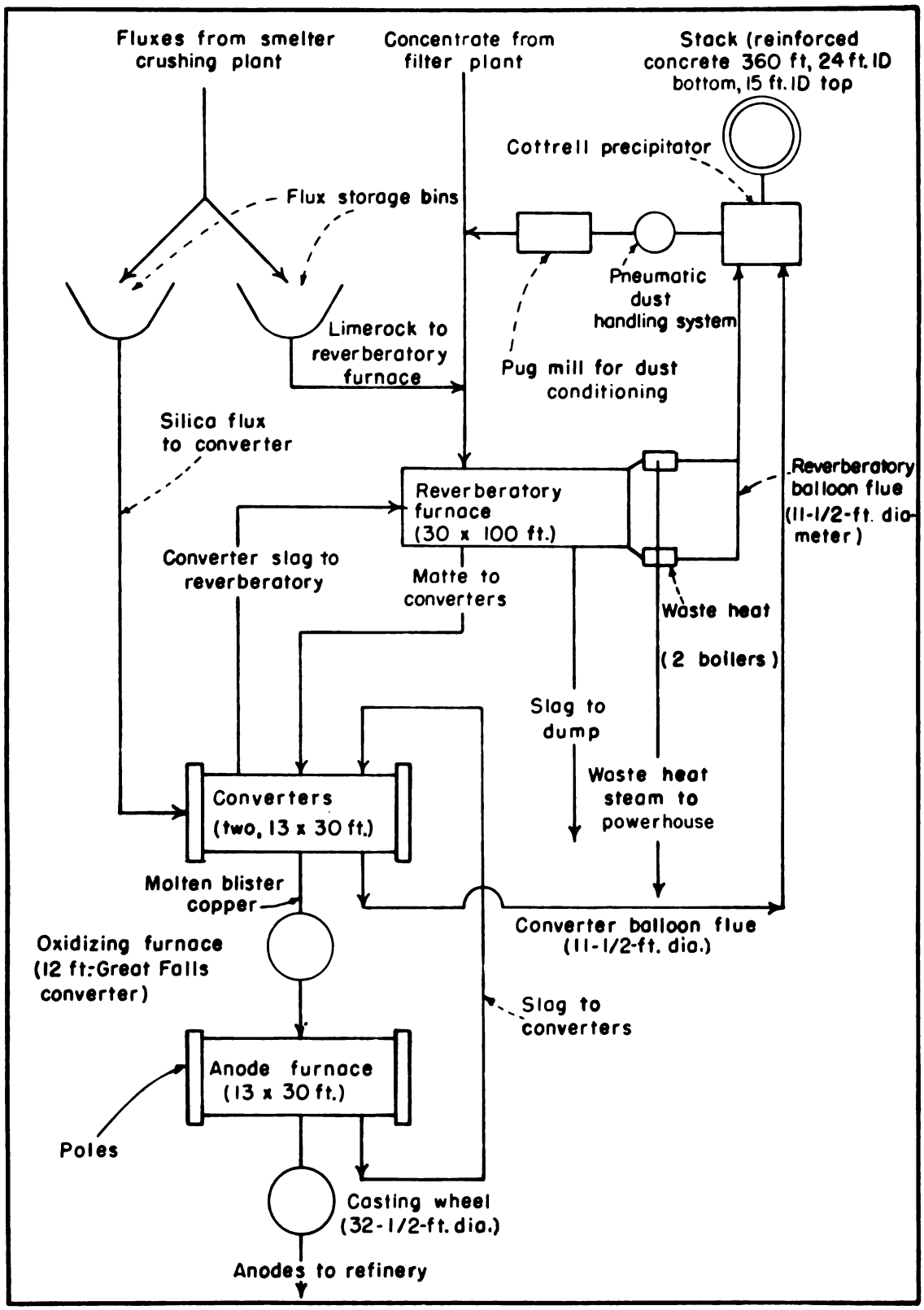
Fluxes from smelter crushing plant
Concentrate from filter plant
Stack (reinforced concrete 360 ft, 24 ft. ID bottom, 15 ft. ID top
Cottrell precipitator
Flux storage bins
Pneumatic dust handling system
Limerock to reverberatory furnace
Pug mill for dust conditioning
Silica flux to converter
Reverberatory furnace (30 x 100 ft.)
Reverberatory balloon flue (11-1/2-ft. diameter)
Converter slag to reverberatory
Matte to converters
Waste heat
(2 boilers)
Slag to dump
Waste heat steam to powerhouse
Converters (two, 13 x 30 ft.)
Molten blister copper
Converter balloon flue (11-1/2-ft. dia.)
Oxidizing furnace (12 ft: Great Falls converter)
Slag to converters
Anode furnace (13 x 30 ft.)
Poles
Casting wheel (32-1/2-ft. dia.)
Anodes to refinery

FIGURE 68. - Smelter Flowsheet.

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